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LOMONOSOV AND SOIL SCIENCE

G. V. DOBROVOL'SKIY, Moscow State University

Two hundred and fifty years ago there was born to the family of an Arkhangel'sk fisherman and settler a man of exceptional gifts, who was to later make Russian science and culture famous — Mikhail Lomonosov. There are few important fields of knowledge to which Lomonosov has not made a significant contribution or provoked new profound thinking. It is worthy of note that an ever-growing large number of sciences is recognizing Lomonosov as its founder or as one of its foremost predecessors.

M. V. Lomonosov has played a prominent role also in the development of soil science — one of the important branches of present-day natural science. It is no wonder that the founder of scientific soil science — V. V. Dokuchayev — has paid exceptionally high tribute to the services of Lomonosov in soil science. "Lomonosov", wrote Dokuchayev, "has already long ago expounded in his works the theory which I defended in obtaining my doctorate and he has stated this theory, admittedly, more extensively and in broader generalizations." (5). V. I. Vernadskiy, too, has commented on the great importance of Lomonosov in the history of soil science; he has called Lomonosov "... not only the first Russian soil scientist, but in general, the first soil scientist." (1).

The scientific activities of Lomonosov occurred during the regime of serfdom and feudal oppression of an absolute monarchy, at a time when the rudiments of bourgeois economics had already taken root in Russia. New economic regions of the country were being developed, production was on the rise, home and foreign trade was increasing, and the demand for agricultural products was becoming greater. Sowing areas were being expanded, primarily in the new southern steppe regions of the country; more industrial and commercial crops were being planted; livestock raising was being promoted; plans were being mapped for specialization of certain agricultural regions. Successes in the economic development of Russia during the first half of the 18th Century created prerequisites also for the development of Russian science and culture. However, the ruling class of gentry and landowners, who strove to preserve and strengthen their power under the new economic conditions, became an increasingly greater reactionary force, hindered the spread of education to the people and was guided by a foreign culture, accessible only to the privileged class. A new progressive trend, which fought for the necessity of developing a democratic national culture, furnished increasingly greater opposition to the reactionary trend of the landed nobility. At the forefront of this struggle was the great Russian scholar Lomonosov.

Lomonosov's activities were exceptionally versatile and fruitful. This A. S. Pushkin said in a very graphic description: "By combining an extraordinary strength of will with an unusual power of conception, Lomonosov has embraced all fields of education. The thirst for science was the strongest passion of this soul which was full of passions.

"A historian, rhetorician, mechanician, chemist, mineralogist, artist, and poet, he investigated all and penetrated all..."[1] Lomonsov also "penetrated" into soil, or rather into the nature of the soil-formation process. To understand properly and to appraise fully the importance of Lomonosov to the history of soil science, we must briefly discuss his views on other branches of natural science with which soil science is closely allied and upon which it is based.

It is a well-known fact that chemistry and physics were closest to his heart. He played an enormous role in the development of these sciences. The great service of Lomonosov to science lies in his discovery and experimental demonstration of the law of the conservation of matter, development of the scientific principles of the atomic theory, work with atmospheric electricity, heat, optics, nature of light, research in chemistry, and in the science of silicates and in other branches of chemistry and physics.

No less brilliantly did Lomonosov's genius manifest itself in geology, mineralogy, and geography. He set forth his ideas on these sciences most fully in his book "On the Strata of the Earth" having published it in 1763 as a supplement to his work "The First Principles of Metallurgy." In the words of Vernadskiy this book of Lomonosov's "is throughout the entire literature of the 18th Century — both Russian and foreign — the first brilliant essay in geological science... This is not only an independent scientific work but this is one of the first popular-scientific works in Russian literature." (2). Of unusual interest in this work are the ideas and observations of Lomonosov on the role of endogenous and exogenous factors in the formation of the earth's surface, on the origin of sedimentary rocks, genesis of the minerals of lodes and of organogenic strata — coal, peat, oil. He has described in broad terms and at the same time in very great detail the role of water in the physical and chemical decomposition and creation processes of rocks and minerals, and in the formation of the face of the earth. Especially interesting is the fact that, in depicting the history of the development of the earth, Lomonosov constantly relies on the principle of actualism, thereby anticipating the discovery of this principle in geology by Charles Lyell (4).

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[1] Complete works, Volume 7, Moscow, 1958.

Unusually profound and penetrating are the ideas and views of Lomonosov on such problems in geology and geography as the structure of the earth's inner-core, causes of volcanic phenomena and earthquakes, structure and development of the earth's surface, ascending and descending air currents in the atmosphere, change of climates in the history of the earth, lowering of the snow line in the mountains depending upon their distance from the equator to the poles, and on many other problems.

To Lomonosov is attributed the truly scientific explanation for the origin of fossil remains of plants and animals. He has wholly refuted the "explanations" which had been based on "the Flood" and on other catastrophes. Lomonosov explained the possibilities of finding fossil remains of animals of southern countries in the North by the change in climate caused in turn, by changes in the inclination of the axis of the earth.

Lomonosov was the first to attempt to appraise the role of the migration of elements in the earth's crust and thereby laid down the foundations for modern geochemistry. Vernadskiy wrote that in the works of Lomonosov "...the recognition and understanding of geochemical problems is distinctly and clearly evident. In the St. Petersburg of those days and in the St. Petersburg Academy of Sciences he proceeded along an independent path on which scientific thought has embarked only in our Twentieth Century. He was constantly absorbed in the chemistry of natural bodies, not specifically, but, in general, and as it related to the history of the earth." (3).

Lomonosov exerted an enormous influence on the development of Russian geography. From 1957 until his death he was the head of the Department of Geography of the Academy of Sciences and directed work in preparing a geographic atlas of Russia. His ideas of a Great Northern Sea Route are widely known. It was mainly on his initiative that the famous academic expeditions of Lepekhin, Zuyev, Pallas, and others, which have contributed so much to a knowledge of the nature of Russia, were organized.

The genius of Lomonosov has manifested itself not only in the sciences which were closest to him, but also in those sciences which were not the subject of his constant scientific activities. It is well known, for example, that Lomonosov was not a biologist; however, both in the realm of general theoretical problems in biology and in specialized branches of biological sciences, he has expressed many clear ideas and has observed many interesting facts and phenomena (6).

Lomonosov knew well the flora of the environs of St. Petersburg; he looked after the Botanical Garden of the Academy of Sciences and often visited it. Lomonosov has provided one of the first scientific definitions for tundra, and steppe; he has provided an accurate explanation for the origin of peat of surface bogs. Lomonosov used the microscope to study the structure of plants and plant residues. Many problems of plant physiology attracted his attention. Criticizing the then-widespread theory of plant water supply, Lomonosov established the idea of air supply, thereby anticipating the discovery of the photosynthesis process. From his "Oration on Aerial Phenomena Proceeding from the Force of Electricity" (1753), we know that the first experiments in the field of electrophysiology belong to Lomonosov: he has conducted experiments to explain plant movement under the influence of an electrical current. Certain problems in the physiology of animals and humans also were of interest to Lomonosov, specifically the transfer of irritation in the organism "...along an entire nerve from the nerve end to the brain itself", the specific character of the reaction of the organs of sense to irritants, the sensation of color, etc.

While interested in such a wide circle of problems in the natural sciences, which related both to the world of organisms and to the inorganic world, Lomonosov did not lose sight of the idea of a material basis for the unity of the world. Turning his attention to the difference between organisms and mineral bodies, he laid emphasis at the same time on the unity of live and dead nature as regards their atomic base and the movement inherent to them; "the corpuscles in living and dead animals move, they move in living and dead plants, and they also move in minerals, or inorganic bodies — hence, in all."[2]

The idea of movement and development as an inherent characteristic of all that exists on earth has pervaded all the ideas of Lomonosov on the subject of nature. In his outstanding work "On the Strata of the Earth" Lomonosov appears before us not only as a scholar and materialist, but also as a scientist who is developing evolutionary views on nature: "And, in the first place, it is necessary constantly to remember that the visible corporeal objects on earth and the entire world were not in the beginning created in precisely the same form that we now find them, but they have undergone great changes, as history and ancient geography, compared to present geographic science, show, and as the changes in the surface of the earth which are taking place in our time also reveal... And thus many vainly think that everything we see was so made by the Creator from the beginning, that not only mountains, valleys and waters but also various kinds of minerals came into being with the rest of the world, and therefore it is not necessary to investigate the causes for their differing in their internal properties and distribution. Such opinions are extremely harmful to the development of all the sciences, and consequently to the growth of knowledge of the nature of this earthly sphere, especially as it affects the art of mining. It is very easy for these clever men to be philosophers and repeat the three words which they have learned by heart 'God thus created', in answer to every question instead of discussing the causes involved."[3]

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[2] "276 Notes on Physics and Corpuscular Philosophy. Subjects for Future Study. 1760". Complete works, Volume 1, 1950, page 159.

Lomonosov was not only a foremost scientist and naturalist, but was at the same time a most eminent philosopher and materialist who was far ahead of many famous thinkers and scientists of the 18th Century in this field of knowledge. There is no doubt that it is expressly the many-sidedness and versatility of Lomonosov's knowledge in the field of many natural sciences, his materialistic world outlook and his historical approach to the study of natural phenomena, which has enabled him also in the field of soil science to clarify a number of extremely important problems regarding the origin and development of soils, and to establish thereby the first principles of this science.

Despite the fact that the history of agriculture had amassed, by the time of the 18th Century, a large quantity of practical data on properties of various soils, these data were purely empirical, uncoordinated, and not related to an understanding of the nature of soil formation. There was at this time no soil science as a distinct branch of natural science. The views of scientists -- contemporaries of Lomonosov -- on soil, its origin and properties, were extremely diverse and often were still based on the influence and authority of the ancient world. There was much that was unfounded and contrary to fact, even in the views of the greatest naturalists of that time. Thus, the celebrated Carl von Linné regarded sand and clay as primitive rocks which were then transformed into various minerals. In his famous work Systema naturae (1735) Linné wrote: "I consider only sand and clay as primitive soils; with the help of elements the whole world of minerals has been derived from them. All remaining stones were formed in periods subsequent to the Creation of the World" (12).

Lomonosov rejected these ideas of Linné and developed the quite proper view on the origin of sedimentary rocks as a result of the weathering processes of Volcanic rocks. It is not necessary to prove how much more important a correct solution of this problem is for understanding soil genesis.

Another famous scientist, a contemporary of Lomonosov — the Swedish mineralogist and chemist Valerius, devoted much attention to soils in his work, "The Chemical Principles of Agriculture" (1761). Expressing a number of interesting ideas on soils, he examines and classifies them chiefly as items of mineralogy while the role of soil in plant life is reduced simply to that of support for root systems (11).

Lomonosov has set forth most fully his views on soil and on the soil-formation process in his already mentioned great book "On the Strata of the Earth," Describing in paragraph 122 of this work the topmost layer of soil, Lomonosov, first of all, tries to clear up the problem of the origin of chernozem, implying here by the term chernozem, the most important part of soil — soil humus. Lomonosov does not doubt that "... the origin of chernozem is not mineral, but from two other kingdoms of nature, from the animal and plant kingdoms; this everyone knows..." We know, says Lomonosov, that "an increase in black garden and farm soil" results from animals and plants. "Inhabitable areas and fields fertilized with manure" are proof of this. But what of the source of humus in forests and meadows — "we should give some thought to this and be on the lookout for various facts." In replying to this problem Lomonosov draws with striking perception a picture of the soil-formation process under moss, grassy, and forest vegetation. Having analyzed the characteristics of soil formation under the various types of vegetation, Lomonosov arrives at his concluding argument: "Thus, there is no doubt that Chernozem is not a protoplastic and primitive material but is the product of the rotting of animal and plant bodies with time."[4] No less boldly does he develop the idea that soil appears and is developed as the result of the influence of vegetation on rocks: "Even bare rock mountains often have a verdure of young moss, which later grows black and becomes soil; the soil, being accumulated over a long period, serves later to produce larger moss and other plants."[5]

From these words it is clearly evident that Lomonosov has (more than two centuries ago) formulated with absolute accuracy a thesis for the formation of soil as a result of the influence of the world of organisms on rocks. In this regard he especially stressed the fact that soil, like all natural bodies, is not something fixed and unchangeable; once having appeared, soil changes with time and is developed.

A. A. Yarilov was absolutely right when he turned his attention to the fact that in Lomonosov's work "On the Strata of the Earth", we are dealing with a properly raised problem of the dynamics of the soil-formation process, and a relationship between the soil-formation process and the evolution of plant forms (14). Of course, we must not forget that these problems were raised and explained by Lomonosov in only a very general form. It was not until a hundred some years later that the idea of the plant-surface origin of soils was worked out by

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[3] "On the Strata of the Earth". Moscow — Leningrad, 1949. Page 55.

[4] "On the Strata of the Earth". Para. 125, page 69.

[5] "On the Strata of the Earth". Para. 124, page 69.

Dokuchayev into a systematic scientific theory.

Analyzing the views of Lomonosov on the origin of soil from a present-day standpoint, we cannot help but be amazed at the keenness and accuracy of his reasoning, and at his ability to dissect and observe the very nature of the soil-formation process. It is not by chance that he devotes most of his attention in the problem of soil genesis to the problem of the origin of soil humus, while he associates entirely the formation of soil humus with the activities of the biological factors of soil formation. Is it not then really remarkable that, being in far greater measure a geologist than a biologist, Lomonosov explains the formation of various soils not only as the influence of various rocks, but, to begin with, as the influence of various types of vegetation?! At the same time he does not simply direct his attention to the difference in the properties of soil under various types of vegetation. He correctly explains these differences by the difference in the quantity and quality of plant litter, by dissimilar conditions in the decomposition of plant residues. Is this not a brilliant foreknowledge of the basic principles of modern day teaching on the biological cycle of matter in the soil-formation process? Lomonosov's thinking achieves here an extraordinary acuteness of scientific foresignt. His language is very vivid and precise:

"In forests where there is always verdure, which does not shed its leaves in winter, there is usually present a sandy soil. In our regions this verdure consists of pine forests and spruce stands. On the contrary, there is more chernozem (black earth) in birch stands and in other forests which shed their leaves in the fall. And since we know that the leaf begins to rot on the ground and turns into manure, it is no wonder that from these leaves, sand, clay, and other ground are covered with black earth, the more so as the forest becomes thicker and higher.

"Pine needles, spruce needles, and needles of other similar trees fall to the ground in small amounts but they cannot be compared with leaves. Whenever and wherever we find chernozem in a spruce stand, it is because it is in the vicinity of other trees."[6]

As we can see, Lomonosov has explained fairly well the difference in the influence of coniferous and deciduous forests on soil. The influence of grassy vegetation on soil is described by him in the following words: "The same should apply to meadows on chernozem, where grass is not mowed or is ruined by cattle grazing and turns into manure, causing an increase in the earth's fertility."[7]

Lomonosov regarded the humification of peat as one of the possible means of forming humus-rich soils. "And since we know that moss grows not only in summer, but also in winter under snow, it is no wonder that vegetation, however small, can grow very high, so that in several places it may not even touch bottom. At the same time it is very probable that the vegetation rots underneath, becoming black earth."[8]

However, humus formation and its accumulation in soil depends, says Lomonosov, not only on the type of vegetation. Of great importance also is the nature of the rock and the relief of the area. Sandy rocks, inclining slopes, too low places, are unfavorable, for example, for the accumulation of humus in the soil. "... When a deciduous forest grows on sand, then it is natural to assume that the sand is deep, and the chernozem becomes thick; and where coarse chernozem particles in low areas and on grades are washed far away by rain, the sand, settling more rapidly to the bottom, will be more suitable in its former habitat."[9]

The question of what Lomonosov meant by the term chernozem — whether a genetic type of soil or soil humus — provoked during his lifetime lively discussions in scientific literature. (1, 8, 9, 10, 13, 14). Obviously, Lomonosov used this term to designate humus and to denote, in general black earth, including chernozem as we understand it today. There is no doubt that Lomonosov was familiar with natural chernozem-steppe soil. Describing the character of the earth's surface, Lomonosov mentions along with bogs and tundras, "... steppes, where grass grows on chernozem."[10] Lomonosov already had an idea of the geographic range and variety of soils. We find in his works mention of the soils of tundras, bogs, coniferous and deciduous forests, steppes, and sandy deserts; Lomonosov writes, too, of the soils of Arabia "which are barren due to excess salt," and of "solonchaks," of the Prikaspiyskaya lowland. "The earth's surface has a great amount of salt" says Lomonosov, describing the nature of "tropical countries."[11]

The origin and geography of soils are of interest to Lomonosov not only as a naturalist. He is concerned with the proper utilization of soils in agriculture. In one of his letters to Shuvalov he mentions that the fourth chapter of his old unpublished writings has been devoted to the problem of "improving agriculture". Among the problems treated by Lomonosov "in correcting the Russian atlas" we find a question of "what kinds of grain should be planted so as to obtain more fruitful harvests" (article by Shusev [10]). Lomonosov turned his attention to certain characteristics which distinguish plowed and garden cultivated soils from natural soils. He writes of chernozem "... which is to be fertilized by human hands for sake of fertility and is called plowed and garden earth. It has been a general observation that the more such earth is enriched by fertilizer, the thicker the black layer becomes. The inhabitatable places, especially where there are many cattle, are covered by chernozem; the older the settlement, the thicker the chernozem."[12]

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[6] Ibid. Para. 123, page 68.

[7] Ibid, para. 123, page 68.

[8] "On the Strata of the Earth". Para. 124, page 69.

[9] Ibid. para. 123, page 68.

[10] Ibid, para. 24, Page 25.

[11] Ibid, para. 32 and 33, pages 27 and 28.

[12] Ibid, para. 24, page 25.

Nor did such an important phenomenom as soil erosion escape the attention of Lomonosov. An extract from paragraph 123 of "On the Strata of the Earth" has already been cited where we see the washing by rain of "chernozem particles" from soils situated on inclining slopes. Discussing "Strata of the Earth revealed by nature herself" Lomonosov points out that in "warm regions" heavy rains "not only wash away the top layer of soil, but even move very heavy stones great distances, uproot trees along with their roots, obstruct formations, and cut through furrows and new channels."[13]

Lomonosov turned attention also to buried soils.[14] We always find in his works a large number of keen observations and interesting views which relate directly or indirectly to the study of soils. To analyze the whole rich heritage of Lomonosov in the field of soil science would require special study. However, that which we already know, is proof enough of the enormous role which he has played in the history of soil science. It is quite impossible to agree with the statements which have often been encountered previously in literature that the ideas of Lomonosov in the field of natural science were not valued by his contemporaries and remained forgotten for a long time. Such a point of view is unfounded as regards the history of soil science.

In this regard it is interesting to note that in 1765, that is, two years after the publication by Lomonosov of his work "On the Strata of the Earth," academician I. G. Leman came forward in the first book of the Transactions of the Vol'noye Society on Economics with an article entitled "Difference of Soil in Considering its Economic Use." Leman gives a fairly accurate definition of soil and soil fertility and, following in the footsteps of Lomonosov, examines soil in close association with the vegetation covering it.

The teaching of soil science at Moscow University, which was founded on the initiative of Lomonosov, was begun in 1770. Soil instruction was offered at that time at the University as "Agricultural Domestic Science." M. I. Afonin, professor at Moscow University, who gave this course, devoted his first lecture at a great public meeting of the University in 1771 to the problem "on the use of knowledge, collection, and distribution of chernozem, especially in agriculture." Although the influence of Afonin's foreign teachers — Linné and Valerius, had an effect upon his views, he followed Lomonosov in the treatment of soils. The basis for the classification of chernozems, as proposed by Afonin, was biological and not petrographic — mineralogic, which was more wide-spread in the classifications of this time. He distinguished groups of "chernozems" primarily by the character of vegetation (birch, nut, bog, and others). The idea for the organization of a soil museum belongs to Afonin.

We find an expression of Lomonosov's ideas on soil and soil formation in works of the famous Russian agronomists A. T. Bolotov and I. M. Komov, in works of academician V. M. Severgin, and in works of the celebrated Russian thinker and revolutionist A. N. Radischev, who was likewise engaged in a study of the productive resources of Russia and, in particular, its soils. In his "Oration on Lomonosov" Radischev comments on Lomonosov's "On the Strata of the Earth," provides an original definition for soil, which supplements and develops the ideas of Lomonosov. We cannot but agree with Krupenikov (7) who noted that Radishchev's "Oration on Lomonosov" is a fine refutation of those views which had prevailed up until so recently, as if the ideas of Lomonosov in the field of soil science had remained unknown and had been lost in the subsequent development of soil science. Actually, despite the fact that certain ideas of Lomonosov, who was somewhat ahead of his own time, were developed only considerably later, on a whole, the teaching of Lomonosov on soil had an enormous influence on the subsequent development of science.

Observing the 250th Anniversary of the birth of Lomonosov, we see in him a great scholar, who has brilliantly combined within himself the qualities of a bold thinker and delicate experimenter, theoretician, and practical worker, profound investigator and brilliant popularizer.

Lomonosov's views on the role of thought and experiment in scientific knowledge and on the role of theory and practice are very close to ours. He has correctly stated that, in order to perceive truth, the scientist should not only collect and observe facts, but he should also logically give a meaning to these facts, attempting to penetrate into the very nature of phenomena and to learn to understand the laws. At the same time he warned that rules and laws should be based on precise facts. "It is known to all who practice sciences that rules may be set up without explanation; however, they are not by any means so firm and convincing as to preclude research of their principles; by so doing, an immeasurably greater benefit can be derived."[15]

The following famous words of Lomonosov have become well-known: "From observations a theory is established and through the theory the observations are improved — the best possible means of searching for truth."[16]

Despite the fact that more than two centuries have passed since Lomonosov's time, many of his ideas and thoughts sound surprisingly modern. Such is the case, for example, of his thesis on the advantage of "an alliance of sciences." Not only an increasingly greater differentiation of sciences is taking place in our time, but, concurrently, there is also an increasingly greater interpenetration of the allied fields of knowledge. This is most graphically evident in the present-day stage of development of chemistry, physics, biology, and mathematics. Soil science, too, is employing an ever larger number of research methods adopted from allied sciences. In this regard it is of interest to recall Lomonosov's words: "There is no doubt that sciences render great mutual support to other sciences as physics to chemistry and mathematics to physics" . . .[17]

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[13] Ibid, para. 80, page 46.

[14] Ibid, para. 161, page 89.

[15] "On the Strata of the Earth". Para. 168, page 95.

[16] "Discourse on the extreme accuracy of the sea route". Para. 61, complete works, Volume 4, page 163, 1955.

Lomonosov considered that the biologist should know physics and chemistry well, but that biological science was a value to physics: "Anatomy and botany are useful to physics, for they may afford an opportunity to understand physical principles."[18]

Lomonosov is akin to us also in his views on the role and objectives of science in the life of human society. Lomonosov considered service to the people as the first task of science. He saw in science an important medium for developing productive resources and culture and for improving the life of the people. With great passion, courage, and persistence, Lomonosov strove to spread education to the people and to develop science in Russia.

We are proud of the achievements of our Soviet science and preserve with love and gratitude the memory of our great countryman, that Russian scholar of genius — Mikhail Vasil'yevich Lomonosov.

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THE ROLE OF COMPONENTS OF WATER-SOLUBLE ORGANIC PLANT RESIDUE IN FORMING AVAILABLE (MOBILE) IRON-ORGANIC COMPOUNDS

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Water-soluble organic matter of plant residue plays an important role in soil-formation processes. Many investigators have stressed the importance of these compounds in the formation and accumulation of humus (3, 5, 14, 15) and also in the migration of various organomineral compounds throughout the soil profile (3, 2, 1, 17, 11). Iron-organic compounds, which are capable of moving with the soil solution, especially during development in the soil of reduction processes, occupy a definite place among organomineral compounds. We have studied the quantitative aspect of these processes directly under natural conditions by using lysimetric chromatographic columns (9, 10).

The results of the determinations conducted in the central taiga zone (Komi ASSR) and southern taiga zone (Moskovskaya Oblast', Krasnopolyanskiy Rayon) show that of the mobile iron forms moving throughout the soil profile as part of the soil solution, a large part (40%-80%) is iron, strongly bound with organic matter.

The results of determining organic matter (Table 1), sorbed from the soil of a large quantity of water-soluble organic matter, which contributes to the activation of the biochemical processes throughout the entire soil profile. In our previous studies we demonstrated the great role played by water-soluble organic matter of plant residue in the formation of mobile iron-organic compounds (7, 8). In this regard column data on a large amount of water-soluble matter moving throughout the profile of virgin podzolic and sod-podzolic soils, reveals the great importance of this matter in the movement of iron (and aluminum).

As these processes were subjected to further study, there arose the question of which groups of organic compounds forming part of the water-soluble organic matter determine the formation of organomineral compounds, including the iron-organic complexes.

According to data in literature, low-molecular organic acids and amino acids formed during biochemical processes of plant litter and root residue decomposition belong to the category of such organic compounds. In studies by Rode (12), salicylic, oxalic, and tartaric acids were determined on the basis of potentiometric titration curves and by calculation of the degree of dissociation of non-volatile (or fixed) acids in water extracts from plant litter. Kappen (quoted under 12), in examining the water-soluble matter of coniferous litter, found acids resembling acetic acid. Skrynnikova (13), in a detailed study with soil solutions, points out that in soils under coniferous vegetation the producing factor in a solution of non-volatile organic acids in intensified. Our chromatographic separation into silica gel of water extracts from spruce needles, birch leaves, and moss under various decomposition conditions, and also of water extracts taken from forest litter, has shown that oxalic acid is always present in the composition of organic matter and that citric acid and volatile acids have been detected.

Several investigators have pointed out the possibility of binding iron by high-molecular compounds of polyphenols, tannic acids, polysaccharides acids, and by fulvic acids (1, 11, 14, 19, 21, 23). Compounds, capable of forming with iron complexes depending on type of chelate bond — gluconic and glucuronic acids (22), — also probably play an important role in these processes.

By means of model experiments, we studied the role of individual components from these compounds in forming iron-organic complexes, and tried to separate these groups from the water extracts of plant residue.

In the first series of experiments we studied the capacity of weak solutions of certain low-molecular organic acids and amino acids to extract iron from gley soil. A plowed layer of gleyish sod-podzolic coarse clay loam soil taken from a farm field belonging to the Timiryazev Agricultural Academy (TSKHA) was subjected to gleying. The sample was kept for 21 days at a temperature of 18-20°C under excess moisture conditions. 0.001 n acid solutions were used in the experiments.

The extraction was performed when the soil-solution ratio was 1:2.5 and when interaction time was 5 minutes, after which the suspensions were filtered through double dense blue-covered filters. Iron was determined in the filtrate directly (with α-α — dipyridyl after Fe oxidation by hydroxylamine) and after oxidation of organic matter by hydrogen peroxide (titanometrically).

From Table 2 we see that the greatest amount

Table 1

Amount of carbon retained by adsorbents of lysimetric columns[a]

Soil	Horizon where lysimeter was placed	Thickness of horizon, cm	Amount of C retained by adsorbents, g/m²		% of acid soluble C to total C
			Total C (after Knopp)	Acid-solu- C (0.1 n H_2SO_4 extr.)	
Belyy Rast. Moskovskaya Oblast' (two-year period)					
Strongly-podzolic (dense spruce forest)	A_0	0—4	29,42	4,96	16,8
	A_2	4—25	12,14	3,42	28,1
	A_2/B_1	25—60	17,94	2,70	15,1
	B_1	60—80	5,02	0,72	14,3
Gleyish sod meadow-podzolic (meadow)	A_1	0—10	37,53	9.05	24,1
	$A_1/A_{2}g$	10—18	8,88	1.88	21,1
	A_2	18—30	15,34	0,76	5,0
	Bg	45—60	9,44	1,05	11,1
Komi ASSR (one-year period)					
Strongly-podzolic	A_0	0—7	13,03	6,26	38,0
	A_2	7—16	9,43	2,22	23,5
	A_2/B_1	16—38	4,18	1,85	44,2
	B_1	38—60	21,51	2,53	11,7

[a] Aluminum oxide was used as the adsorbent in the columns for chromatography. Senior laboratory worker M. N. Rytikova assisted in analytical treatment of data.

Note: Comma represents decimal point.

Table 2

Extracting iron from gley soil by organic acid solutions

Organic acids, 0.001 n	Fe converted to FeO, mg/100 g of soil		Bound Fe	
	Before oxidation	After oxidation (total)	mg/100g of soil	% of total
Formic	1,10	4,83	3,73	77,0
Oxalic	1,12	2,06	0,94	45,6
Citric	2,85	3,39	0,54	15,9
Succinic	1,12	2,06	0,94	45,5
Malic	0,60	2,06	1,46	71,0
Lactic	0,80	1,33	0,53	40,0

Note: Comma represents decimal point.

of iron is extracted by solutions of formic and citric acids. Formic, malic, oxalic, and succinic acids form more stable compounds with bivalent iron. Adding small amounts of organic acids to water extracts from plant residue noticeably increases their capacity to extract and bind iron. Thus, in one of the experiments, solutions of citric and formic acids were added to water extracts from spruce needles. The results of the determination have shown an appreciably greater amount of extractable iron when adding citric acid: the amount of iron passed into the extract was 9 mg, including ~ 50% represented by stable compounds, from which iron is determined only after the oxidation of organic matter. Comparing these results with data in Table 2, we see an increased capacity of a citric acid solution to form stable complexes with bivalent iron when adding citric acid to extracts from spruce needles (16%- and 47%). This difference may be associated with the influence of pH (pH in the first experiment is 3.6 and in the second 4.9) . There is in literature an indication of the influence of the medium's reaction on the formation of stable iron-organic complexes (6, and 18). These authors note that a certain increase in pH is conducive to complex formation.

Our experiments on the study of kinetics of the complex formation process of iron with organic acids have shown that as much as 20% of added iron is bound in a 24-hour period into stable complexes.

We note in literature that a number of low-molecular organic acids formed during the decomposition process of plant material may be found to be stable in soil solutions (12, 13) and, as the foregoing results of our experiments have shown, they have the capacity to form with ferrous iron of gley soil stable soluble iron-organic complexes. Presence of such acids in water-soluble organic matter of plant residue increases their extraction capacity with respect to the ferrous iron forms in the soil. These complexes may be formed under acid reaction conditions typical for podzolic and sod-podzolic soils.

Different amino acids are formed during decomposition of plant residue and transformation of soil organic matter (5). Thus, Davidson, Souden, and Atkinson (20), using paper chromatography, discovered in an organic fraction of soil 30 amino acids, and among them, leucine, proline, valine, isoleucine, glutamic, and aspartic acids. Of course, the amino acids may be relatively quickly subjected to microbiological decomposition (deamidization), but this does not exclude the possibility of their participation in the mobile iron-organic complex formation.

The capacity of water-soluble organic matter from birch leaves and hay (clover + timothy) to extract iron from gley soil was noted in our experiments (8). Examples of formation of eluvial horizons beneath grassy vegetation under steppe conditions are proof of this. The nature of the extracts from such plant residue and the rate of their gradual change reveals the presence in the solution of protein compounds and amino acids.

We analyzed the following amino acids in our experiments: glycocoll, valine, leucine, aspartic acid, glutamic acid, lysine, and histidine. Conditions for conducting these experiments were similar to those of the previously described experiments with organic acids. Experiments showed (Table 3) that of these amino acids solutions of aspartic and glutamic acids, valine, and glycocoll, have the greatest capacity to extract iron from gley soil. Besides, a large share of extractable iron (~ 50%) was represented by stable complexes, where iron can be determined only after the oxidation of organic matter. Data on the adsorption of iron from these acids in ionites is proof of the stability of bivalent iron complexes with aspartic and glutamic acids. Two grams of ionites (KU-2 in H form and AV-16 in OH form) were placed in a chromatographic column 10 cm high and 1.5 cm in diameter. Twenty ml solutions each were passed through the columns (Table 4).

We see from Table 4 that a large part of the iron being extracted by these acids passes through the KU-2 cationite and almost completely through the AV-16 anionite.

Tannic acids (tannins) in simple and condensed form are an important component of water-soluble organic matter formed during decomposition of plant residues (6). Predominant among tannic acids are the tannides, which, during hydrolytic decomposition influenced by tannase-type of fermentation, decompose with the formation of phenol type compounds (pyrogallol or pyrocatechin). Compounds of this type characterize presence in their aromatic structure of phenol hydroxyls, and, in certain cases, also of carboxylic groups, which determines their capacity to interact with various cationites. Assuming that a given group of compounds may play an important role in iron migration, we made an attempt to show quantitatively the importance of this group of compounds in forming stable water-soluble iron-

Table 3

Extraction of iron from gley soil by 0.001 n solutions of amino acids

Amino acids	pH of solutions	pH of solutions after interaction with gley soil	FeO, mg/100 g of soil		
			After oxidization of organic matter (total)	Before oxidation	Bound
Glycocoll	4,90	8,12	1,16	0,61	0,55
Valine	6,10	7,92	1,30	0,32	0,98
Leucine	6,33	8,15	0,83	0,38	0,45
Isoleucine	6,15	7,76	0,83	0,32	0,45
Aspartic	4,15	7,40	1,35	0,52	1,23
Glutamic	5,55	8,12	1,35	0,61	0,74
Lysine	5,35	8,15	0,83	0,61	0,22
Histidine	5,10	7,75	0,83	0,38	0,45
0.01 n H_2SO_4	—	2,15	20,50	5,20	15,30

Note: Comma represents decimal point.

Table 4

Stability of binding iron by certain amino acids

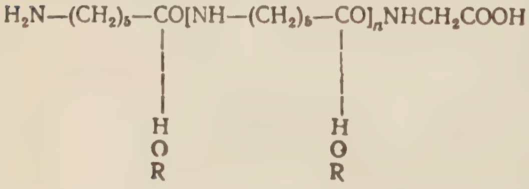
Treatments	FeO, mg/liter of solution		
	Before passage through adsorbent	After passage	Retained by adsorbent
Passed through KU-2			
Solution after interaction of gley soil with glutaminic acid	5,4	4,4	1,0
Same, with aspertic acid	5,4	1,7	3,7
Passed through AV-16			
Solution after interaction of gley soil with glutamic acid	5,4	5,0	0,4
Same, with aspartic acid	5,4	5,1	0,3

Note: Comma represents decimal point.

organic compounds.

As a result of the variety of chemical structure of tannides it is impossible to conduct an analytical quantitative determination of all plant tannins with the help of any reaction. Therefore, we took as the basis for determining their total amount the sorption reaction on sorbents. Mikhalov (6) proposed as one of the sorbents, a polyamide resin "caprone," an amphoteric compound having two active end-groups NH_2 and COOH. The molecular weight of the polyamide is as much as 6,000. The amount of free amino groups is very small — ranging from 0.06 to 0.07 meq. per g of "caprone" sorbent.

Structure of the caprone resin is:



$$H_2N{-}(CH_2)_5{-}\underset{\substack{|\\|\\H\\O\\R}}{CO}[NH{-}(CH_2)_5{-}\underset{\substack{|\\|\\H\\O\\R}}{CO}]_nNHCH_2COOH$$

Tannides are sorbed chiefly by a stable hydrogen bond of phenol hydroxyls with polypeptide groups of a "caprone" polyamide. The free end amino groups bind a small amount of phenol hydroxyls or hydroxls of carboxylic groups of free organic acids depending on type of salt formation.

Nature of the method. Water extracts from plant material or litter are divided into two portions. In one of them the total content of dry matter (dry residue) is determined by evaporation. The other portion is "untanned" by five-minute shaking with "caprone" polyamide, which is supplied beforehand with a small amount of water. The residue derived after evaporation of the filtrate from this portion gives an idea of the content of soluble compounds not retained by "caprone", termed in analytical practice of non-tannides. The amount of tannides is defined as the difference between the content of soluble matter and non-tanides.

Table 5 gives results of the determination of tannides in water extracts from plant residue decomposed under dissimilar conditions, at varying periods of decomposition, and from different layers of litter as well as in natural surface waters. The methods used in the experiments on decomposition of plant material have been described in one of our previous studies (7).

We see from Table 5 that tannide content is, on an average, 25%-55% of the dry residue of the extract. Tannides are abundant also in natural surface waters — as much as 30%-50% of the dry residue, according to our determinations. It is interesting to compare relative tannide content in water soluble organic matter (Table 6).

Comparison shows great differences in the relative content of tannides (from water-soluble organic matter) in water extracts from plant litter (of various types). Thus, if tannide content in spruce and moss litters totals 80%-90% of the water-soluble organic matter, it amounts to a total of only 30%-50% in extracts from birch leaves. As a result, polyphenol type compounds are predominant in water-soluble organic litter decomposition products under coniferous moss forests, while in birch litter there are more non-tannide type compounds.

In this regard it would be appropriate to cite studies by Coulson, Davies, and Lewis (19) who have shown that in surface coarse humus material of mor type there are considerably more polyphenols (quantitatively and qualitatively) than in fine humus formations of the mull type.

Data obtained shows that tannide type compounds may form a large part of the water-soluble

Table 5

Content of tannides in water extracts from plant residue in soil surface waters and in litter extracts

Treatments	Decomposition time and sampling period	Moisture during plant matter decomposition	Weight of dry residue, g/liter	Tannide content	
				g/liter	% of dry residue of initial solution
Extract from:		optimum	0,2670	0,1494	55,9
Spruce needles	Two weeks	excess	0,5280	0,2928	55,4
"	"	optimum	0,0580	0,0391	67,4
Sphagnum moss	"	excess	0,1900	0,1459	76,7
		optimum	0,7410	0,1236	16,6
Birch leaves	"	excess	1,5260	0,3941	25,8
		optimum	0 4290	0,2468	57,5
Mixed coniferous-deciduous litter	"	excess	0,6090	0,3171	52,0
Surface water					
From Plot 1[a]	May 9, 1959	—	0,0520	0,0260	50,0
Same, 2	"	—	0,0660	0,0330	50,0
" 2	June 10, 1959	—	0,0820	0,0530	65,0
" 1	May 11, 1960	—	0,1880	0,0671	35,6
" 2	"	—	0,2460	0,0605	28,1
Extract from:					
Spruce litter From plot 1[a]	"	—	—	—	—
A_0' 0—2 cm	"		0,1130	0,0757	66,6
A_0'' 2—5 cm	"	—	0,0670	0,0297	44,3
Moss cover Plot 2					
A_0' 0—3 cm	"	—	0,0240	0,0183	76,2
A_0'' 3—7 cm	"	—	0,0410	0,0186	45,4
Mixed litter from Plot 2					
A_0' 0—3 cm	June 30, 1960	—	0,0420	0,0132	31,4
Spruce litter from Plot 1					
A_0' 0—2 cm	"	—	0,6780	0,1720	25,3
A_0'' 2—5 cm	"	—	0,6510	0,1150	17,6
Moss cover from Plot 2					
A_0' 0—3 cm	"	—	0,6870	0,1810	26,3
A_0'' 3—7 cm	"	—	0,3320	0,0160	4,8
Mixed litter from Plot 2					
A_0' 0—4 cm	"	—	0,1990	0,1010	50,7

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[a] Moskovskaya Oblast', Belyy Rast. Plot 1 — a strongly podzolic soil, dense spruce forest; Plot 2 — gleyish podzol, moss, mixed forest. For detailed description of these plots see Izvestiya of Timiryazev Agricultural Academy, 1958, No. 5.

Note: Comma represents decimal point.

Table 6

Content of water-soluble organic matter and tannides in water extracts from plant residue

Solutions from:	Moisture during plant matter decomposition	Tannide content in g/liter	Water-soluble organic matter content in g/liter	% of tannides from water-soluble organic matter
Spruce litter	optimum	0,1494	0,1658	90.01
Same	excess	0,2928	0,3628	80,70
Sphagnum moss	optimum	0,0391	0,0463	84,4
Mixed coniferous-deciduous litter	optimum	0,2459	0,2936	88,7
	excess	0,3171	0,3972	79,8
Birch leaves	optimum	0,1236	0,3627	34,0
Same	excess	0,3941	0,7598	51,8

Note: Comma represents decimal point.

organic matter of soils of the forest meadow zone. To explain the role of these compounds in extracting iron, we compared the results of extracting iron from gley soil during action on it by initial extracts from various layers of plant litter and of plant residue (spruce needles, birch and oak leaves) and by the same extracts but passed preliminarily through "caprone."

Methods used to conduct these experiments were the same as those in the previously described experiments with organic acids. Results are given in Tables 7 and 8.

We see from Tables 7 and 8 that, in the first place, adsorption of tannides in "caprone" is accompanied by a shift in pH toward alkali concentration, which is caused, probably, by adsorption of a certain amount of carboxyl-containing compounds by the principal end-group (the NH_2 group); secondly, we note in all cases a decrease in the extraction capacity of the solutions with respect to iron after sorption of tannides in "caprone" (especially in cases with spruce litter); and, thirdly (Table 8), a large part (from 64% to 30%) of extractable iron is represented by fairly stable compounds, which is indicated by the capacity of the iron of these compounds not to be sorbed and pass through such a strong cationite as KU-2.

Data in Table 8 shows, likewise, that solutions derived from spruce needles will form more stable complexes with iron. Removing tannides from the solutions decreases the absolute amount of iron being extracted from gley soil: a considerable decrease in the amount of this iron is observed in the case of solutions from

Table 7

Effect of tannides on extraction of iron from gley soil, mg/100 g

Solutions derived from litter, sampled June 1959 in plots	pH of solutions		Weight of dry residue in g/liter	Tannide content		FeO, mg/100g of soil
	Initial	After interaction with soil		g/liter	Fr. dry residue of init. solu.	
Spruce plot, Plot 1 A'$_0$ 0-2 cm	4,8	4,4	0,3800	0,2670	70,5	2,44
Same solution passed through "caprone" resin	6,1	4,7	0,1130	—	—	1,80
A''$_0$ 2-5 cm	4,7	5,3	0,1680	—	—	3,11
				0,1165	69,0	
Same solution passed through "caprone" resin	6,0	4,4	0,0515	—	—	2,36
Moss, plot 2 A'$_0$	5,5	5,8	0,0800	—	—	2,88
0-5 cm				0,0400	50,0	
Same solution passed through "caprone" resin	6,1	4,7	0,0400	—	—	1,67

Note: Comma represents decimal point.

Table 8

Effect of tannides on extraction of iron from gley soil

Solutions from plant residue (24-hour standing)	pH of solutions	Tannide content		Iron extracted from gley soil		Iron adsorption from solutions by KU-2 cationite in H form		
		g/liter	% of dry residue of initial solution	Fe, g/100 g of soil	In solution, %	Initial solution mg/liter	Aft. passage thru KU-2, FE, mg/liter	% of iron passed through KU-2
Spruce needles	5,2	0,1816	30,5	8,58	100	22	14	63,9
Same solution passed through "caprone" resin	5,9	—	—	3,9	45,5	10	7	70,0
Birch leaves	4,73	0,5456	16,4	32,8	100	84	22	26,2
Same solution passed through "caprone" resin	5,40	—	—	26,5	80,4	68	14	20,6
Oak leaves	4,98	0,0676	44,5	38,2	100	96	30	31,3
Same solution passed through "caprone" resin	5,56	—	—	22,6	59,3	58	26	45,0
Distilled water	5,7	—	—	2,34	—	—	—	—

Note: Comma represents decimal point.

spruce needles (by more than 60%). At the same time solutions passed through "caprone" have the capacity also to form stable complexes with iron. This is due to the fact that in water extracts from plant residue there are, along with tannic acids, compounds called nontannides. We may include in this group of compounds the simplest phenols, organic acids, substances containing nitrogen, carbohydrates (hexoses, and pentoses), and the polycondensation and decomposition products of these substances.

Thus, formation of stable complexes of iron is associated not only with tannic acids (tannins) but also with organic acids and amino acids.

Conclusions

1. A large amount of organic matter moves as part of the soil solution in a forest meadow zone in temporary excessively moist virgin soils under forest and meadow vegetation; this determines the high activity of the biochemical processes in such soils at an appreciable depth of profile.

2. There is a large quantity of tannin-type compounds in the water-soluble organic matter of natural soil waters and water extracts from a litter of wood species as well as organic acids of the aliphatic series.

3. Many low-molecular organic acids, amino acids, and tannin-type compounds have the capacity to form with soluble ferrous iron forms in gley soil, stable water-soluble iron-organic compounds, which reveals the important role of these water-soluble organic matter components in soil in the movement of iron.

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FORMATION AND SUBDIVISION OF FOREST FLOOR IN SOUTHERN TAIGA CONIFEROUS FORESTS[1]

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Forest floor is formed from litter of trees, shrubs, and grasses, which, in decomposing, enriches the soil with organic and mineral substances. The forest floor, with its specific physical and chemical properties, influences the hydrothermic and air regimes of soils, and the natural restoration and growth of forest stands. Morozov (6) has stressed the enormous role of forest floor in the life of a forest. He wrote: "If the forest is a great soil former, it is primarily due to this litter and to those climatic conditions which are being created by the forest beneath its canopy and which determine the humic character of this dead cover."

Various types of litter are formed in various types of forest. Müller (20), at the end of the nineteenth century, distinguished, in beech forests of Denmark, two principal types of forest floor or forest humus: [2]

1. Mull, or mild humus, or sweet humus;
2. Dry peat or coarse humus, acid humus (Rohhumus).

According to Müller, mull is characterized by intimate mixture of a residue of forest litter with the mineral part of the soil, friability, finely blocky, or granular structure, increased porosity, and a weakly acidic or neutral reaction. Mull is formed in beech forests having vigorous soil animal activity, especially earth worms. Almost all soil aggregates in mull consist exclusively of worm coprolites.

Dry peat, or coarse humus (Rohhumus), is characterized by compact structure and is formed with the help of beech roots and fungi binding it. Acting as a carpet, the peat covers the soil without becoming mixed with it. Coarse humus consists of semi-decomposed plant residue, often well distinguishable by eye, and formed without or only with slight participation of animals. This humus is characterized by a sharply pronounced acid reaction.

Müller's study has attracted the attention of silviculturists and soil scientists of many countries and served as an incentive in explaining the role of climate, soil, and vegetation in the formation of forest humus types.

Thus, Hesselman (1925) [3] ascertained that mull is formed in the moist and mild climate of Central Europe, while a coarse humus is formed in the cold and damp climate of Switzerland, as a result of the slowing down of plant residue decomposition and nitrogen mobilization.

Under one and the same climatic conditions the formation of various types of forest humus is associated with the composition of forests and soils (17, 20). Hesselman observed cases of mull formation when there was a large amount of lime in soils, and coarse humus formation when there was a lime deficiency in soils. A change in vegetation may also result in the evolution of coarse humus into mull (17).

A study of forest humus, which had been begun after Müller in many countries, revealed a variety of forest humus types and different methods of approach in classifying it. Thus, in American literature (18), coarse forest humus had been begun to be divided into: raw humus, peat, acid humus, duff, mor, and others. Mull type had been begun to be divided into: mild humus, leaf mold, neutral humus, or mull.

Many classifications for forest humus were also proposed in European countries (21). The problems of the difference in concept and classification of forest humus were widely discussed at the Third International Congress of Soil Science, and from the proposal of Bornebusch and Heiberg (1937), the following resolution was adopted: determination of forest humus species is to be based on morphological characteristics and only two main types of forest humus may be recognized to exist: mull and mor.

It is suggested that by mull we mean a mixture of organic matter with the mineral part of a soil of granular structure, with a gradual transition into the lower horizons. Mull is subdivided by extent of organic matter participation into:

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[1] Research was under direction of Professor S. V. Zonn.

[2] We use the term "forest floor," while abroad the term "forest humus" is used.

[3] Quoted under Handley (17).

1. Fine mull — >50% organic matter; 2. Coarse mull — 20%-5%; 3. Firm mull — <5% organic matter. To the mor type is related organic matter which has not become mixed with mineral soil, usually more or less compacted organic matter.

Mor has been subdivided into two layers: the fermentative F-layer, consisting of already turned-brown plant residues, and the humified H-layer, consisting of decomposed and semi-decomposed organic residue. It was proposed to distinguish three species of mor from the character and thickness of the F and H layers:

1. Granular mor — a strongly pronounced H-layer, having a fine granular structure; 2. Greasy mor — a somewhat thin F-layer, slightly fibrous; a thicker H-layer, compact, greasy; 3. Fibrous mor — F- and H-layers of well-expressed fibrous character, with, in addition, in the H-layer slightly decomposed plant residue visible.

A more detailed separation of the various types of humus with respect to their formation conditions has been proposed in the foreign studies cited under (22) and (23). All these classifications are based on principles suggested by Müller.

Following Morozov's studies, we decided to divide forest humus in our country into two types: mild or neutral, and coarse or acid (11, 15). In most cases by forest humus we understand forest floor, that is, we are applying Müller's concepts.

Despite the fact that we are using the concepts of mull and mild humus interchangeably (as synonyms), we must point out the difference between them (2). In the mull described by Müller plant litter is completely mixed through animal activity with the mineral part of soil, and is made up basically of worm coprolites. In mild humus, as we see it, there is no complete mixing of the litter with the mineral part of soil; predominant in mild humus is the more decomposed organic matter which is well isolated from the mineral soil horizons. Mull (after Müller) is one of the soil types or rather a humus horizon of the soils (A_1). Our mild humus is one of the types of well-decomposed forest litter. Such a distinction is due to plant litter decomposition characteristics under continental and Atlantic climate conditions. Stepanov (11) has pointed out that "...sharp differences in climatic zones, soils, and forests between our country and Denmark do not make it possible to transfer automatically the results of investigations to our soil but demand independent research in this field." A dry, hot summer in our forest-steppe and steppe zones, where mild humus is chiefly formed, slows down the activity of soil fauna.

In summarizing, we might say that, at present, all forest floors are divided into two great groups: coarse humus or slightly decomposed, and mild humus or strongly decomposed (2). It has been assumed that coarse forest floor is formed chiefly in coniferous forests, and mild humus forest floor in deciduous forests. An intermediate type of forest floor is formed in mixed forests.

However, this division, in our opinion, is too general, and requires greater detail, because within each of the groups of forest floor there are many species which differ in morphology, physical, and chemical properties. Certain species already have been separated into coarse and mild forest floor in the resolutions of the Third Congress of Soil Science in 1935. A description of various species of forest floor by types of forest can be found in many studies by our scientists (3, 4, 11, 14). We see from these studies that the formation of a specific species of forest floor is closely allied with the type of forest. Therefore, a study of forest floor should be distinguished by formations and within the formations, by types of forest, which differ from one another in accumulation and decomposition conditions of forest floor, and consequently, in the nature of the forest floor itself. Based on this, we undertook the task of studying the character of forest floor in the various types of coniferous forests, and of showing the conditions under which specific species of forest floor are formed, and the relationships between forest floor and the forest and soil, which is absolutely required to develop a forest floor classification.

Research was carried out at the Northern Station of the Forestry Laboratory, Academy of Sciences, USSR, located at the Rybinskiy Forest Yaroslavskaya Oblast'. The forests of the Rybinskiy Forest are typical of the southern taiga subzone, which permits us to distribute the results of our investigation over the entire subzone. Several strongly-pronounced types of spruce and pine forests (after Sukachev [12]) were taken from the forest. A brief description of the plots on which a study of forest floor was made is given in Table 1.

A detailed description of the morphology of forest floor, measurement of floor thickness and its amount has been provided for all types of spruce and pine (except the pine forest with Polytrichum and Pogonatum moss). In describing forest floor we noted the following characteristics: separation of forest floor from the soil, i. e., a definite boundary with the soil, division into subhorizons, clear separation of subhorizons, and description of them with respect to color, compactness, composition, and condition of plant residue, presence of roots and hyphae, and moisture.

Thickness and amount of forest floor were measured by traverse lines intersecting the experimental plot at representative areas. The forest floor was cut on these lines at each meter with a round template (d = 20 cm) having a sharp lower edge, and the litter thickness was measured on the sectional walls in four places. Every five samples, cut by knife, were gathered together and weighed for the purpose of determining the amount of forest floor. A total of fifty to sixty measurements of thickness of forest floor was made in each forest type, and 25-30 samples were taken. In measuring thickness of individual subhorizons of forest floor, the same template was used to cut the forest floor down to the soil, and the distance between the upper edge of the template, serving as the level, and a specific subhorizon was measured,

Table 1
Brief description of coniferous types of forests. Rybinskiy Forest

Forest type	Composition	Age	Site quality	Predominant cover	Soil
Mountain sorrel -fern spruce	10S occas. B[a]	80—90	1.5	Spring wood-fern oxalis	Sod-weakly podzolic, sandy loam, and coarse clay loam on moraine clay loam
Mountain sorrel -whortleberry-spruce	7S2B1A	100—120	III	Whortleberry-oxalis	Thin podzol, pseudo-gley, sandy loam, on moraine clay loam
Whortleberry-spruce		100—120	IV	Whortleberry, green moss, sphagnum in the depres.	Thick podzol, gleyish sandy loam on red brown clay moraine
Horsetail-sphagnum spruce-birch	7S3B occas. A	100—120	IV—V	Sphagnum, forest horse-tail	Peaty-podzolic, gleyish coarse clay loam, on moraine coarse clay loam
Lichen-pine	10P	65—70	III	Lichen	Podzol of average thickness, sandy, on glacial sandy deposits
Red bilberry-pine	10P	70—75	III	Red bilberry	Thick podzol, sandy, on glacial sandy deposits
Whortleberry-pine	10P + B	70—80	II	Whortleberry, green moss	Thick podzol, sandy, with gleying spots from a depth of 80-90 cm, on ancient alluvial deposits
Long stem moss-pine	10P + B	60—70	III—IV	Haircop moss	Thick podzol, sandy, gley, on ancient alluvial deposits

[a] S = spruce; B = birch; A = aspen; P = pine.

carefully removing them one after another. Bulk density was computed based on measurement of thickness and weight of individual subhorizons. Malyanov (3) and Skorodumov (9) used similar methods to measure thickness and bulk density of forest floor.

The data obtained from these measurements was processed by statistical methods. Computations showed that the number of measurements made was, in most cases, adequate for obtaining a required accuracy within 5%.

To compare the amounts of forest floor and the bulk densities of the individual subhorizons in various forest types, we determined the moisture of forest floor and converted all results to absolutely dry weight.

To determine character of distribution of forest floor by thickness and to show the predominant type of forest floor in a whortleberry spruce stand, we mapped the forest floor by marking off an area 40 x 50 m (0. 2 ha) into 5 x 5 m squares inside of which we measured on cut samples total thickness of forest floor and its individual subhorizons. Measurement data were plotted on a map.

Forest floor is not homogeneous throughout its entire profile; in most cases we can distinguish in it several genetic subhorizons differing in the extent of plant residue decomposition. In studying forest floor we confined ourselves to our own accepted separation of forest floor into subhorizons (3, 10, 11, 13).[4] The entire forest floor is written as A_0, and its subhorizons A_0^1, A_0^2, and A_0^3. In addition, we proceeded from the following characteristics, typical of each of them:

A_0^1 — almost undecomposed litter of the previous year, which has only changed color.

A_0^2 — semi-decomposed fermentative plant residue with easily distinguishable parts.

A_0^3 — Homogeneous black mass without clearly distinguishable plant residue.

We used this division and designation for the slightly coarse humus and coarse humus forest floor formed under normal moisture conditions or in conjunction with initial stages of excess moisture.

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[4] Abroad, the entire litter is referred to as A_0 but its subhorizons are L, F, H.

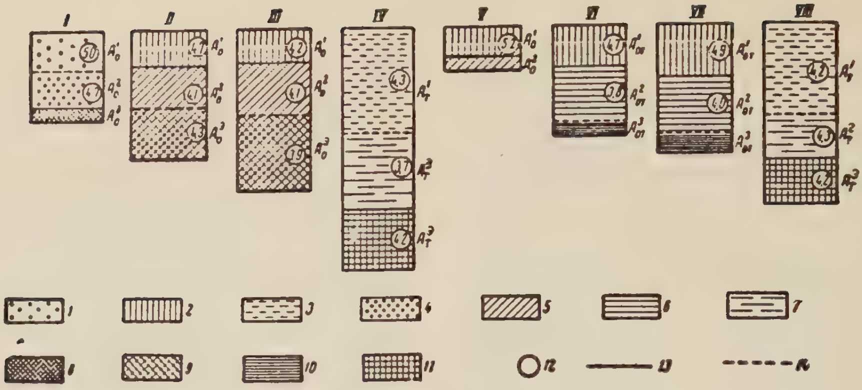

Fig. 1. - Structure of a profile of forest floor in coniferous forests of the southern taiga.
I - mountain sorrel-fern spruce; II - mountain sorrel-whortleberry -spruce; III - whortleberry-spruce; IV - horsetail-sphagnum spruce-birch; V - lichen-pine; VI - red bilberry - pine; VII - whortleberry, pine; VIII - longstem moss-pine. Undecomposed litter: 1 - mild litter, consisting of woody litter, fern, and mountain sorrel; 2 - coarse litter from needles of branches and semishrubs; 3 - mild litter from longstem moss and sphagnum. Semi-decomposed plant residue; 4 - mild, friable, easily raked; 5 - coarse, compacted; 6 - coarse, compacted, with signs of peatiness; 7 - mild residue of sphagnum and longstem moss. Decomposed organic matter; 8 - well-decomposed, greasy; 9 - coarsely decomposed; 10 - peated; 11 - similar to peat; 12 - pH value; 13 - boundary between subhorizons, distinct; 14 - indistinct.

We assigned to slightly coarse humus forest floor the mild, friable forest floor, the A_0^3 of which is in transition from coarse humus to mild. The coarse humus forest floor is compacted, coarsely decomposed, distinctly isolated from the soil; in the A_0^3 the plant residue is visible only under microscope.

Whenever the subhorizons A_0^2 and A_0^3 display signs of peat formation the entire forest floor is termed A_{ot} and its subhorizons A^1_{ot}, A^2_{ot}, and A^3_{ot}. Peat forest floor is usually compacted, coarsely decomposed, with strongly pronounced stratification. If the forest floor was formed during excess moisture, and if its lower subhorizon was similar to peat[5] we could call the entire forest floor A_T and its

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[5] When the lower subhorizon ($A^3{}_T$) is characterized by great thicknesses, the subhorizon will become peat, which is the case with bogs. However, a study of bogs has not been included in our objectives.

Table 2

Thickness and amounts of forest floor in coniferous types of forest. Rybinsky Forest, Yaroslavskaya Oblast'

Forest type	Thickness of forest litter, cm					Amt. of forest fl. (dry mass) metric tons/ha
	M	±*m*	±*p*	±*σ*	±*V*	
Mountain sorrel-fern-spruce	3,0	0,09	3,0	0,57	19,0	24,0
Mtn. -sorrel-whortle. -spruce	4,3	0,11	2,6	0,55	12,7	34,0
Whortleberry-spruce	5,4	0,16	3,0	0,83	15,3	47,5
Same (data obt. during map.)	5,7	0,08	1,4	1,40	24,7	—
Horsetail-sphagnum spruce-birch	16,0	—	—	—	—	74,0
Lichen-pine	1,4	0,03	2,1	0,14	10,0	12,9
Red bilberry-pine	3,6	0,10	2,8	0,53	14,7	38,2
Whortleberry-pine	4,2	0,14	4,3	0,68	16,2	38,0

Note: Comma represents decimal point.

subhorizons A^1_T, A^2_T and A^3_T.

The results of studying many samples of forest floor have made it possible for us to distinguish by morphological structure the following types, which, for greater clarity, are presented in the form of a diagram (Fig. 1).

Thickness and amount of forest floor depend upon amount of annual litter and rate of its composition. Ratio of the accumulation and decomposition processes does not remain constant during the course of a year; hence, thickness and amount of forest floor have been subject to intense fluctuations even within one forest type (Tables 2 and 3).

We see from Table 2 that the thickness (3 cm) and the amount (24 metric tons/ha) of forest floor in a mountain sorrel-fern spruce stand are minimal and are the greatest in a horsetail-sphagnum spruce-birch type (16 cm and 74 metric tons/ha). In pine stands the smallest thickness (1.4 cm) and amounts (12.9 metric tons/ha) are in the lichen type, where litter from trees is the sole source of litter. According to Melekhov's data, (4), the amount of annual litter in red bilberry — and whortleberry-pine stands is 2-3 times greater than in lichen — pine stands. A comparison of the amount of forest floor in a red bilberry — pine grove (38. 2 metric tons/ha) and in a whortleberry bush-pine grove (38. 0 metric tons/ha) of varying thickness may be explained by the more compact forest floor in the red bilberry-pine stand (Table 3).

Thickness of forest floor also has been subjected to intense variations within one forest type, which is especially clearly evidenced in mapping forest floor in a whortleberry-spruce stand, where the coefficient of variation is 24.7%. The thickness of individual subhorizons of forest floor have been subjected to even greater variations (Table 3).

Data on the determination of bulk density of individual subhorizons (Table 3) shows that the forest floor in pine stands is more compact than

Table 3

Thickness and bulk density of subhorizons of forest floor in various types of forest. Rybinskiy Forest

Forest type	Subhorizon of forest litter	Thickness of subhorizons, cm					Bulk density of subhorizons, g/cm³
		M	$\pm m$	$\pm p$	$\pm \sigma$	$\pm V$	
Mountain sorrel-fern, spruce	A_0^1	1,6	0,07	4,3	0,45	27,0	0,07
	A_0^2	1,4	0,07	5,2	0,45	33,5	0,07
	A_0^3	Not det'd.					
Mountain sorrel-whortleberry-spruce	A_0^1	1,2	0,06	5,1	0,49	42,0	0,08
	A_0^2	1,4	0,06	4,2	0,47	33,1	0,09
	A_0^3	1,7	0,05	2,9	0,36	21,2	0,12
Whortleberry-spruce	A_0^1	1,1	—	—	—	—	0,09
	A_0^2	1,8	0,08	4,5	0,35	19,7	0,09
	A_0^3	2,5	0,10	4,0	0,46	18,4	0,11
Same (data obtained during mapping)	A_0^1	1,0	0,02	1,9	0,32	31,0	—
	A_0^2	2,1	0,03	1,4	0,53	25,2	—
	A_0^3	2,6	0,05	1,9	0,92	35,4	—
Horsetail-sphagnum spruce-birch	A_T^1	7,0	—	—	—	—	0,03
	A_0^2	5,0	—	—	—	—	0,04
	A_0^3	4,0	—	—	—	—	0,09
Lichen-pine	$A_0^1 + A_0^2$	1,4	0,03	2,1	0,14	10,0	0,09
Red bilberry-pine	A_{OT}^1	1,3	0,10	7,7	0,50	38,4	0,10
	$A_{OT}^2 + A_{OT}^3$	2,3	0,09	3,9	0,45	19,5	0,28
	A_{OT}^1	1,7	0,08	4,8	0,33	19,4	0,11
Whortleberry-pine	$A_{OT}^2 + A_{OT}^2$	2,5	0,05	2,0	0,18	7,5	0,15

Note: Comma represents decimal point.

in spruce stands. In all forest types bulk densities increase with depth, i. e., with the increase in the extent of forest floor decomposition, and conform well with forest floor structure (Fig. 1).

We should mention that not only are large variations in thickness typical of the forest floor of mountain sorrel-whortleberry and whortleberry-spruce stands but also the well-known variety of forest floor structure, which is associated with a strongly pronounced microrelief in these forest types. The presence of hillocks, old overgrown tree stumps, overturned trees, and saucer-shaped depressions is responsible for material changes in the composition of the cover over the soil. Small flat and elevated areas are covered with whortleberry, green moss, and mountain sorrel: sphagnum appears in the depressions. The structure of forest floor on flat areas is seen in Figure 1. Forest floor in microdepressions, where a sphagnum cover has been developed, has the following structure: A^1_{ot} — woody litter and dead sphagnum stocks, A^2_{ot} and A^3_{ot} — peated.

In areas where birch and aspen leaves play a large role in the formation of forest floors a strongly-pronounced stratification of forest floor, as a result of the binding of leaves by mycelium is found; transition to soil is gradual, while in the soil there is a small A_1 horizon.

With all varieties of forest floor present, mapping of a whortleberry-spruce stand has shown that coarse humus, occupying 79.1% of the area, is the predominant type of forest floor. Peaty forest floor is found in the depressions and covers 20.9% of the area.

In various forest types the composition of plant residue, as a forest floor component, also has an effect on its character. In a mountain sorrel-fern spruce stand, fern and mountain-sorrel, along with woody litter, play a large role in the formation of forest floor; in mountain sorrel, whortleberry, and whortleberry-spruce stands the litter from trees and difficulty decomposing semi-shrubs (whortleberry) serves as the principal material. In a horsetail-sphagnum spruce-birch type of forest the decisive role belongs to sphagnum. Quantitative participation of grasses in formation of forest floor has not as yet been adequately explained.

The character of plant residue, as a forest floor component, and soil moisture affect firstly, the formation of forest floor and its specific morphological properties, thickness, and amount. Normal moisture conditions in a mountain sorrel-fern spruce stand contribute to excellent decomposition of plant residue and to formation of a slightly coarse humus forest floor of small thickness and amount. In mountain sorrel-whortleberry, and whortleberry spruce stands, where decomposition conditions are made more or less difficult, because of temporary excess moisture, there is formed a coarse humus forest floor of average thickness with great amounts and with signs of peat formation. Forest floor in a horsetail sphagnum spruce-birch type of forest with almost constant excess moisture has a peat character, maximum thickness, and amounts. Zonn (2), too, noted an increase in the amount of forest floor during transition from spruce stands with moss to whortleberry stands, and then to sphagnum types.

We see a similar picture in pine stands. In a lichen — pine stand there is formed a coarse thin, forest floor having a small content of forest floor not only as a result of a small quantity of annual litter but also because of unsatisfactory decomposition conditions. In red bilberry and whortleberry-pine stands the thickness and amount of forest floor are greater, while the forest floor itself shows signs of dry peatiness. In moss — spine stands longstem and sphagnum-pine stands, where the forest floor is of peat character, thickness, and amounts of forest floor are greatest as a result of excess moisture (4, 5). However, the formation of coarse humus and peaty forest floor in pine stands occurs under conditions different than those in spruce stands. In pine stands (red bilberry shrubs, whortleberry shrubs) coarse humus and peat development of forest floor is the result of inadequate moisture in the upper horizons of the soil, great compaction, and low moisture capacity of the forest floor itself. Inadequate moisture results in retarding plant residue decomposition and leads to the formation of a dry peat state. In spruce stands coarse humus and peat formation, in most cases, are brought about as a result of excess moisture and deteriorated (decreased) aeration conditions, which favors the development of rotting processes and leads to slowing down decomposition.

Data on determination of organic matter[6] composition points out the differences in the litter decomposition processes in whortleberry-spruce stands and in whortleberry-pine (Table 4). The degree of decomposition of forest floor in the lower subhorizons is greater in a pine stand than in spruce (ignition, loss in a pine stand is 75. 28%, C:N ratio is 15.2, while in a spruce stand ignition loss and C:N ratio are 83. 7% and 17. 7%, respectively).

Group composition of humus also differs in forest floor. In a spruce stand there are more available humus substances (humic acids and fulvic acids) than in a pine stand, while, on the other hand, there is less difficulty hydrolyzable residue. In transition from the upper subhorizon (A_0^1) to the lower subhorizons (A_0^2 and A_0^3) we see in a forest floor of spruce stands an increase in the amount of humic and fulvic acids at the expense of a decrease in difficulty hydrolyzable residue (from 48.3% to 38.1%). In pine stands we note a decrease in available humus matter and an increase in difficulty hydrolyzable residue (from 46.4% to 52.8%). It is precisely due to this difficulty hydrolyzable residue that a peaty forest floor is built up in whortleberry-pine stands.

Thus, a study of the morphological structure, and certain data on organic matter composition of forest floor in coniferous forests of the southern taiga confirm the accuracy of the assumption that each forest type has its own distinctive certain type of forest floor. In the spruce and pine forests which we examined, there are two predominant types of forest floor: coarse humus and peaty.

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[6] Data has been kindly submitted to us by D. F. Sokolov.

Table 4

Brief description of forest floor. Rybinskiy Forest (after data of D. F. Sokolov)

Forest type	Subhorizon[a]	Depth, cm	pH of water suspension	Determined in dry matter, %				Group composition of humus			$\frac{\text{C of humic acids}}{\text{C of fulvic acids}}$
				Ignition loss	Total amount C	Total amount N	C:N	c, % $\frac{\text{dry matter}}{\text{C of investigated matter}}$			
								Humic acids	Fulvic acids	Difficulty hydrolyzable residue	
Whortleberry-spruce	A_0^1	0—5	4,32	91,42	46,30	2,825	16,4	$\frac{6{,}76}{14{,}5}$	$\frac{8{,}57}{18{,}6}$	$\frac{22.39}{48{,}3}$	0,79
	$A_0^2\ A_0^3$	5—8	3,65	83,70	41,61	2,346	17,7	$\frac{8{,}83}{21{,}2}$	$\frac{10.67}{25{,}6}$	$\frac{15.84}{38{,}1}$	0,83
	A_2	10—20	4,20	2,97	1,29	0,099	13,0	$\frac{0{,}25}{19{,}4}$	$\frac{0.40}{31{,}0}$	$\frac{0.38}{29{,}6}$	0,63
Whortleberry-pine	A_{OT}^1	0—3	4,98	82,75	43,11	1,558	27,7	$\frac{5{,}04}{11{,}7}$	$\frac{5.30}{12{,}3}$	$\frac{20\ 00}{46{,}4}$	0,95
	$A_{OT}^2\ A_{OT}^3$	3—7	3,70	75,28	33,42	2,205	15,2	$\frac{4.68}{14{,}0}$	$\frac{6.25}{18{,}7}$	$\frac{17.65}{52{,}8}$	0,75
	A_2	10—20	4,55	0,60	0,28	0,075	3,7	$\frac{0.05}{17{,}9}$	$\frac{0{,}07}{25{,}0}$	$\frac{0.10}{35{,}7}$	0,71

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[a] Designation for subhorizons as adopted by us.

Note: Comma represents decimal point.

Changes in thicknesses and amounts of forest floor depend upon accumulation and character of litter decomposition, which is to the greatest extent determined by soil moisture and by composition of forest vegetation, or by forest type. When soil moisture increases, the thickness and amount of forest floor increases, while forest floor changes from slightly coarse humus to peat depending upon character of decomposition.

Coarse humus and peat development (formation) of forest floor in spruce and pine forests are due to various causes: in spruce forests, to excess moisture, in pine forests, to inadequate moisture, which is expressed also in the composition of organic matter being accumulated by them.

Various forest types have the following forest floor:

Spruce: mountain sorrel-fern — slightly coarse humus; mountain sorrel-whortleberry and whortleberry — coarse humus; horsetail-sphagnum-spruce-birch — peat. Pine: lichen-coarse humus; red bilberry and whortleberry — peaty; with longstem moss — peat.

Qualitatively, the following is suggested for determining basic types of forest floor in pine and spruce forests of the taiga zone:

Slightly coarse humus. Thickness no greater than 3 cm, very mild and friable. Slightly bound by grass roots. Subhorizons A_0^2 and A_0^3 very similar, consisting of undecomposed and partly semi-decomposed woody litter and dead stubble and leaves of rapidly decomposing fern and mountain sorrel. A_0^3 — very fine, represented by well-decomposed black material, pierced by small roots. Transition to A_1 horizon gradual.

Coarse humus. In spruce stand, thickness of forest floor is, on an average, 5-6 cm, in pine stand up to 2 cm. In both formations forest floor is compact, consisting of coarse plant residue with predominance of woody litter and dead parts of semi-shrubs (red bilberry, whortleberry) or of lichens (in dry types). In lichen — pine stands the forest floor is subdivided into two subhorizons, and in spruce stands into three subhorizons.

A_0^1 — undecomposed litter, easily raked, and separated from A_0^2 and A_0^2; A_0^2 consists of litter scraps and fragments bound by roots. Gradual transition to A_0^3 — a coarsely decomposed brown mass with various bits of bark and cone. In dry pine stands A_0^3 is often absent. Transition to A_1 or A_2 horizons abrupt.

Peaty. In spruce stands thickness is 6-8 cm, compact, coarsely decomposed, subdivided into: A^1_{0t} — woody litter, and sometimes dead sphagnum, A^2_{0t} and A^3_{0t} — well developed, stratified, consisting of black or brown peat-like mass. In pine stands — thickness is 3-5 cm, with strongly pronounced stratification into A^2_{0t} and A^3_{0t}, compact, thickly pierced by small roots: A^3_{0t} — poorly expressed and similar to brown peat granules.

Peat. Thickness is 8-10 cm and greater; mild, consisting of well separated subhorizons: $A^1{}_T$ — dead layers of sphagnum, or cinnamon-brown stubble of haircap moss, among which are clearly discernible needles, branches, and leaves of woody litter; A^2_T — brown semi-decomposed layers of dead moss with branches, cones, and pieces of bark; $A^3{}_T$ — mass of black peat.

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CHARACTERISTIC WATER-PHYSICAL PROPERTIES AND WATER REGIME OF FOREST SOILS OF THE CENTRAL KAMCHATKA RIVER VALLEY

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A study of the water regime of soils of the Central Kamchatka River Valley is of great interest not only for explaining the character of soil-formation processes on volcanic deposits and determining the genetic nature of soils, but also for revealing basic patterns of plant water consumption.

In previous works on the study of Kamchatka soils (2, 10, 14) we encountered morphological descriptions and a description of the chemical properties, whereas there are almost no data on water-physical properties and the water regime of the soils of the Kamchatka River Valley. This study will, to a certain extent, make up this deficiency.

Objectives and Methods of Study

Research was carried out by coworkers of the Forestry Laboratory, Academy of Sciences, USSR, under the direction of Professor S. V. Zonn, as part of a Kamchatka Comprehensive Expedition, Siberian Department, Academy of Sciences, USSR, in the region of the Kozyrevskoye Forest Reserve, three kilometers northeast of Kozyrevskoye village. [1]

Studies were conducted on experimental plots measuring 0.5-1 ha, laid out in various forest types (Table 1), on the right bank of the Kamchatka River, (60-70 cm above sea level).

Soil moisture was determined by the gravimetric method (by drying samples at 105°C). Soil samples were taken with a borer, replicated three-to-five times. The water-physical properties of the soils were determined by acceptable methods (1, 8).

An experiment on the study of moisture condensation in the soil was conducted following Lebedev's (9) methods. A soil sample with an undisturbed structure was placed in a metal box and isolated by guaze to prevent direct contact with the soil. The experiment was carried out in eight replications in two treatments: in the first treatment — the soil sample was exposed from above and below, while, in the second, the soil sample was exposed only from above. Roots were calculated in monoliths (50 x 50 x 10 cm), taken at a distance of one meter from the trunk.

A morphological characteristic of the soil is the presence in the profile of soil layers of a varying color and a rather distinct texture. Thus, at a depth of 2-4, 12-14, 25-30, 40-48, 105-110 cm, we note layers of light volcanic ash. A layer of coarsely granular "gravel" is found at a depth of 50-60 cm, while at a depth of 30-40 cm, and 80-180 cm, we find a layer of finer texture.

Climatic Conditions

The Kamchatka River Valley (Kamchatka Depression) is surrounded on all sides by mountains. The Sredinnyy Kharchinskiy, Valaginskiy, and other mountain ridges protect the valley from the effect of sea winds, which explains the comparatively continental climate of this region.

Minimum winter temperatures are -45° to -50°C, maximum summer temperatures +28° to +30°C, mean annual temperature 1.67°C, sum of temperatures during the growing period (a stable transition of 5°C) is 1600-1700°C. Typical are late (beginning and middle of June) and early (end of August, and beginning of September) frosts with an average monthly temperature in June of 10°-14°C and in September 7°-10°C. There are about 80 days without frost.

According to data of the Kozyrevskaya Meterorological Station for 1956-1960, the mean annual precipitation in the region of the station is 395 mm. The precipitation in summer (June-August) is 34% of total annual precipitation. Evaporation during the growing period equals 260-270 mm. As a result of such distribution in precipitation and the high amount of evaporation during the growing period, the role of soil in plant water supply is particularly important, because the water regime of plants depends upon the capacity of these soils to hold and conserve moisture, the basic amounts of which are created in soils in the spring, during the melting of snow.

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[1] Participating in this study, besides the authors of this article, were S. N. Likhtmakher, A. V. Grachev, V. V. Stefin, A. T. Dembo, and B. V. Sheremet.

Table 1

Description of the subjects of study

Exp.plot No.	Forest type	Profile No.	Composition of forest stand/1 story	Total	Age, years	Reforestation site classification	Total number of stems per ha	Soil (field designation)
1	Shrub-grass larch	1	10L + B	4L + 6B + A	250	III—IV	692	Peat-coarse humus
2	Shrub-grass birch after larch forest (1942 cutting)	2	9B+1L	9B+1L	65	IV	217	Same
3	1960 cutting after shrub-grass larch forest	93	9B+1L		Birch—65	"	—	Same
12	Birch with varied grasses	9	9B+1A+L	9B+1A+L	90	"	706	Sod, coarse humus
11	Beach-grass-aspen	8	10A	9A + 1B	140	II	642	Peaty-sod

Temperature Regime of Soils

The temperature regime of the soil (Fig. 1a) shows that the soil is warmed primarily by the warmth of the air. An increase in air temperature results in an increase in the temperature of the surface layers of soil and in the spread of a heat wave into the soil's lower layers. The warming of surface layers lasted in 1959 until the end of August and beginning of September, followed by a cooling off of the soil surface. The heat wave still continued to be spread into the lower horizons. The warming of the soil at a depth of 250 cm evidently ceased during the second half of October, which is confirmed also by 1960 data.

The great thickness of the snow cover (50-60 cm), according to our data and Tsvid's (15) data, is responsible for the shallow freezing of the soil (no lower than 80 cm). The frozen horizon thaws out comparatively slowly. We observe freezing in the Kamchatka River Valley soils up until around June 30. We find in the valley, spots of permafrost (15), as was observed in the alasy,[2] near the village of Lazo, and on excess moisture soils in the regions of skerries or rocky islets. On the whole, we see only seasonal freezing. The frozen layer of soil in the valley thaws out from above and below; thawing occurs from above as a result of continual increase in air temperatures, spread of heat into the lower horizons of the soil profile, and heat of percolating melted snows; thawing occurs from below from the heat of the deeper layers (Fig. 1a).

The basic difference in soil temperatures is seen to be a function of forest type, character of forest stand, and thickness of forest floor. Thus, on June 22, 1960, we studied a frozen horizon: on a 1942 cutting (where there were many slashings from cutting) at a depth of 40 cm; on Experimental Plot No. 1 at 44 cm, in an aspen stand at 46 cm; and in a birch stand at 51 cm.

Daily fluctuations in air temperatures do not bring about a change in soil temperatures below 40 cm. The temperature of deep soil layers depends only upon the total seasonal change in air temperature. We may assume that the heating of soils is determined chiefly by the thickness of forest floor, heat conductivity of surface ash deposits, heat capacity and moisture of the soils. Soil color, obviously, does not play a vital role, because the forest stand and herbaceous cover prevent the soil from being directly heated by the sun's rays and this is the result of heat exchange in the soil-air system.

A study of the temperature regime of soils showed that a frozen layer which impedes root penetration and activity in the deep layers of soil, is found in the soils of the valley for a significant part of the growing period (up to the beginning of July) at a depth of 40-80 cm. However, as we see from the data on Dadykin (5) and Orlov (11), seasonal freezing only delays root activity and affects redistribution of the basic root mass, but does not bring about the destruction of root hairs; consequently, root activity is restored after the soil thaws out. But because up to the end of July the temperature at a depth of 50-80 cm does not rise above 5°C, the roots are spread chiefly in the upper 30-40 cm (larch, aspen) and even in the 20 cm (birch) layers,

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[2] Alasy are woodless strips covered with grassy vegetation. (TRANSLATOR'S NOTE: Alasy are lands on Kamchatka devoid of woody vegetation and used as hay fields).

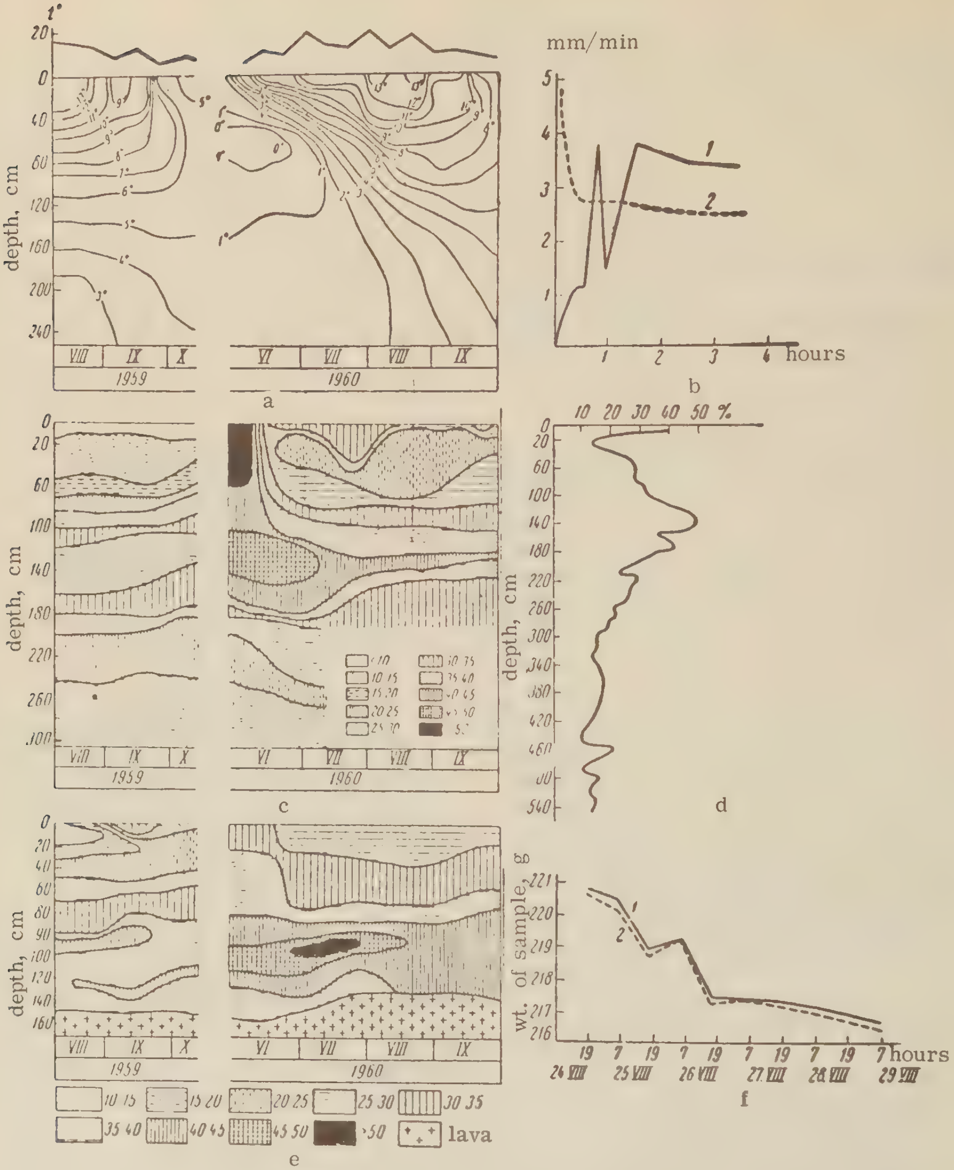

Fig. 1. - Temperature (in degrees) and water (in % of absolutely dry weight) regimes of soil on Experimental Plot No. 1.
a - temperature chronoisopleths; b - water entry into soils, mm/min; 1 - frozen horizon June 18; 2 - without frozen horizon August 21; c - moisture chronoisopleths; d - soil moisture throughout the profile, July 1, 1960; e - moisture chronoisopleths (Experimental Plot No. 2); f - change in moisture of surface soil layer under natural conditions: 1 - frozen layer; 2 - thawed layer.

Water Physical Properties of Soils of the Kozyrevskoye Forest Reserve

By texture all these soils belong to the coarse silt and fine sandy loams. We observe in the soil profile an alternation of layers with various ratios of these fractions (Table 2). We observe at a depth of 42-48 cm and 160-170 cm that the soil begins to become finer up to the point of becoming coarse clay loam.

An important characteristic of soils (Table 3) is the low value of bulk density. Within the first meter this value does not exceed 0. 8. A similar value for bulk density was noted also beneath birch stand and in the coarse clay loam and clay loam soils of the Shchapinskiy Forest. Low bulk density is due, in the first place, to

Table 2

Particle-size analysis of soil (Experimental Plot No. 2), g

Depth, cm	Solution loss	Diameter of particles, mm							
		1—0,25	0,25—0,10	0,10—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	<0,01
0—17	2,19	—	—	53,20	31,04	7,00	6,28	2,48	15,76
17—24	0,94	—	—	60,60	27,60	3,80	5,58	2,42	11,80
25—30	1,22	1,44	17,68	32,12	35,61	0,78	8,44	3,93	13,15
30—42	1,49	3,76	12,56	34,19	34,11	7,34	4,40	3,64	15,38
42—48	0,52	3,38	6,84	23,02	43,64	13,84	5,68	3,60	23,12
50—60	0,79	9,61	11,22	31,53	31,64	8,28	5,81	1,91	16,0
75—85	0,64	—	—	50,28	37,40	5,20	4,08	3,04	12,32
105—110	0,57	—	7,15	29,93	37,64	9,68	11,67	3,93	25,28
130—140	2,27	—	—	34,26	46,45	8,33	6,64	4,37	19,29
160—170	2,98	—	—	20,64	53,35	11,22	9,52	5,27	26,01

Note: Comma represents decimal point.

Table 3

Water-physical properties of the soils of the Kozyrevskoye Forest Reserve

Depth, cm	Bulk density, g/cm³	Particle density	Porosity, %	Maximum hygroscopic moisture, %	Field, moisture capacity, %
0—10	0,70	—	—	13,74	47,9
10—20	0,76	2,60	70,8	3,10	28,8
20—30	0,80	2,54	68,5	5,04	23,9
30—40	0,80	2,47	65,7	2,67	35,2
40—50	0,79	2,47	69,8	3,83	31,1
50—60	0,80	2,53	69,1	5,44	32,8
60—70	0,80	2,53	69,1	5,44	33,7
70—80	0,80	2,46	68,7	4,62	29,6
80—90	0,80	2,46	66,2	3,51	34,9
90—100	0,80	—	Not det'd.	3,75	40,7
100—110	0,79	—	"	3,99	34,8
110—120	0,91	2,86	68,0	5,28	40,3
120—130	1,04	—	Not det'd.	6,57	41,7
130—140	1,18	2,51	56,0	7,80	41,8
140—150	1,28	—	Not det'd.	7,88	48,3

Note: Comma represents decimal point.

the large amount of volcanic glass in the soil; secondly, to high porosity of separates and, thirdly, to the loose composition of soil particles, which is the result of the separation of these ashes from the air after volcanic eruptions. Redeposition of ashes by water results in a sharp increase in their bulk density (up to 1. 3). The coarse texture of soils is responsible for their low sorption capacity. Maximum hygroscopic moisture attains a relatively high value only in the upper peaty horizons. In mineral layers of soil the maximum hygroscopic moisture value approaches that of sandy loams.

The small amount of maximum hygroscopic moisture is not correlated with a high field moisture capacity of soils (it corresponds more likely to the field moisture capacity of fine clay loams rather than sandy loams). It is possible that a high field moisture capacity is due to high porosity and stratification of soils and to the formation of a large amount of capillary-enclosed (Jaminchain type) moisture.

We must consider the fact that, although field moisture capacity was determined according to instructions of S. I. Dolgov and N. A. Kachinskiy, it does not correspond to the moisture of minimum moisture capacity of Rode (12), because its physical nature is not so uniform and this water includes gravitational-supported-water (especially at the boundaries of separation of layers).

On the whole, water-physical properties of soils are conducive to development of vegetation: a large amount of available water and, at the same time, a comparatively large number of aerated pores — more than 50%. But the extreme friability of the soil layer and puffed soil, according to observations of Chizhikov (14), increase the tendencies to wind-fall of trees, and possibly the rugged and gnarled trunk of birch stand is an adaptation of these trees to these conditions. According to our observations, we note an adaptation to swelling of the upper soil layers and even of larch, which forms so-called "bottled" — bottle-shaped swelling in the butt-end, reaching a height of 1-2 m. Swelling or thickening of the butt-end shifts the center of gravity closer to the base and increases the area of support, which definitely increases stability of tree.

Looseness of soil, according to P. N. Chizhikov, also makes the exchange between soil and plant roots difficult, especially of young plants. Young plants quickly consume nutrient substances and moisture from the volume of soil surrounding them, and they are subsequently developed under an inadequate supply of nutrients, despite the fact that the total amount of these nutrients and the number of their available compounds are considerable.

Capillary rise of water in the soil (and thereby the amount of water lost through evaporation) is made difficult, on the one hand, by the coarse texture of soils and, on the other hand, by the stratification of the soil profile. Fine layers of a few millimeters thickness of finer texture, or with a different pore configuration, considerably lower the water-lifting capacity of soils (7).

The presence in the soil profiles of a frozen horizon at a depth of 40-50 cm has made it necessary to conduct a determination of its water permeability. The water permeability of a frozen layer (Fig. 1b) is very low and is practically equal to zero, because the ordinarily frozen layer has been saturated with water since fall and the water, which has frozen in the pores, forms a barrier obstructing the movement of melted snow. The total porosity of a frozen layer does not change during freezing. As the layer thaws out, the water permeability of the soil increases sharply, which (after the first hour of observation) is associated with the percolation of water through a gravelly coarsely granular interlayer.

After the soil thaws out, a constant fairly high water permeability is established (water permeability was somewhat higher when determined in tubes). In the fall water permeability was determined using the frame method. As would be expected (based on data in the literature (4)), this method yields an appreciably lower amount of water permeability than the tube method but, nevertheless, is sufficiently high — 2.39 mm in a quarter of an hour. Consequently, these soils may be related to the well water-permeable group, assimilating a large part of the winter and all of the summer precipitation. Likewise it is obvious that the water should lie stagnant at the upper limit of freezing. This possibly explains why at this depth there is a finer soil texture which, in turn, may make percolation of moisture difficult.

Root Distribution in Soil

Data on root contents show that the greatest number of roots is found in larch (as compared with birch and aspen). In addition, 89.8% of larch roots is formed in the 0-40 cm layer; at a depth of 70-80 cm we note only 1% of root mass, but the absolute amount of root contents in this layer is 196 kg/ha (Table 4).

Compared with larch, birch roots are even more concentrated in the upper layers (88.8% in the 0-20 cm layer, and 97.1% in the 0-40 cm layer). The total root contents in birch are somewhat less than in larch.

We observe less amounts of roots in aspen. But, a greater percentage of aspen roots penetrates below 40 cm (19.6%). There is almost the same percentage of aspen roots at a depth of 70-80 cm as larch roots (752/kg/ha) at this depth.

A sharp decrease in the percent of aspen roots at a depth of 20-30 cm is possibly associated with the large quantity of undecomposed coal-remains of larch once having grown here -- found in this layer.

An analysis of root distribution by fractions (diameters of >5 mm and < 5 mm) reveals that the greatest percentage of fine roots is found in larch, followed by birch, with the smallest number in aspen. But aspen surpasses birch in the number of fine roots in the deep layers of the soil (40-80 cm) and in their percentage of fine roots, as compared with large roots, increases sharply in all species in the lower horizons of the soils. Thus, based on the analysis of the growth of the root system, we may expect larch to expend considerably more water than birch and aspen.

Soil Moisture Regime

Observations of soil moisture were begun in the middle of the 1959 growing period. A dry summer in 1959 (for June-August precipitation was 75.8 mm of which 37.1 mm occurred in June) resulted in the fact that at the time of observation the upper 60 cm soil layer under larch had dried to 40%-50% of field moisture capacity (Fig. 1c). Maximum drying was recorded in the zone of principal root distribution (10-50 cm). In the deeper soil layers (10-180 cm) the moisture increased sharply and reached a maximum in the 120-160 cm layer. Below 180 cm soil moisture decreased. By the middle of September the moisture percentage in the 10-60 and 60-150 cm layers dropped appreciably. Fall rains (end of September) increased the amount of moisture in the upper layers of soil, and as a result of a downward flow of water, a second maximum was formed in the 110-130 cm layer. Below 160 cm soil moisture decreased and below 300 cm it was constant. It is evident that below 300 cm the water percolated in small quantities and very slowly (Fig. 1d). Moisture was expended principally from the upper 10-60 cm layers.

Table 4

Root distribution by soil layers

Species	Depth, cm	Weight of roots g	Wt. of roots kg/ha	% of total wt. by horiz.	Wt. of root diam. >5 mm kg/ha	% of wt. of frac. >5 mm in diam. by horiz.	Wt. of roots <5 mm in diam kg/ha	% of wt. of frac. < 5 mm in diam. by horiz.	% of frac. <5 mm in dia. to total frac.	% of frac. >5 mm in dia. to tot. frac.
Larch	0—10	650,0	26000	33,3	15600	25,5	10400	61,8	40,0	60,0
	10—20	642,0	25680	32,9	22800	37,3	2860	17,2	11,3	88,7
	20—30	426,0	17040	21,8	16400	27,0	640	3,8	3,7	96,3
	30—40	35,9	1436	1,8	740	1,2	696	54,2	48,5	51,5
	40—50	71,0	2840	3,7	2080	3,4	760	4,5	28,2	71,8
	50—60	28,0	1120	1,7	724	1,1	396	2,3	35,4	64,6
	60—70	75,2	3008	3,8	2752	4,5	256	1,6	8,5	91,5
	70—80	19,9	796	1,0	—	—	796	4,6	100	0
	0—80	1948,0	77920	100	61096	100	16824	100	21,5	78,5
Birch	0—10	911,0	36440	48,8	33600	50,5	2840	35,1	7,8	92,2
	10—20	746,0	29840	40,0	28160	42,4	1680	20,9	5,6	94,4
	20—30	85,7	3428	4,5	2208	3,3	1260	15,6	36,7	63,3
	30—40	70,6	2824	3,8	2068	3,1	756	9,3	26,8	73,2
	40—50	20,0	800	1,1	320	0,5	480	5,9	66,7	33,3
	50—60	140,0	560	0,8	220	0,3	340	4,2	66,7	33,3
	60—70	7,7	308	0,4	—	—	308	3,8	100	0
	70—80	10,5	420	0,6	—	—	420	5,2	100	0
	0—80	1865,5	74620	100	66536	100	8084	100	10,8	89,2
Aspen	0—10	263,5	10540	29,2	8440	28,6	2100	33,6	20	80,0
	10—20	189,0	7560	21,1	6120	20,7	1440	23,1	19	81,0
	20—30	12,1	484	1,6	88	0,3	396	6,4	82	18,0
	30—40	255,0	1020	28,5	9800	33,2	404	6,5	4	96,0
	40—50	54,4	2176	6,1	1628	5,5	548	8,8	25	75,0
	50—60	59,8	2392	6,6	1920	6,5	472	7,6	20	80,0
	60—70	40,7	1628	4,2	1160	3,8	468	7,6	28	72,0
	70—80	18,8	752	2,8	348	1,3	404	6,4	54	46,0
	0—80	893,3	35732	100	29504	100	6232	100	21	—

Note: Comma represents decimal point.

Spring observations of soil moisture, immediately following the melting of the snow in 1960 (Fig. 1c, d) revealed that the upper boundary of the frozen layer at a depth of 40-50 cm is, as was to be expected, a characteristic water barrier responsible for the first moisture maximum. A second maximum, having survived from the previous year, increases still more at a depth of 130-140 cm. The upper soil maximum holds until the frozen layer increases and then the water partially flows into the lower horizons. The year 1960 was comparatively rainy and water losses from the soil were considerably less. But, despite this fact, small periods of drought were accompanied by great losses of water from the horizon within the root layer. The moisture maximum at a depth of 120-130 cm was preserved until late fall, although the absolute maximum value decreased somewhat.

An analysis of the soil moisture of the 1942 cutting confirms these patterns (Fig. 1e). In this soil, lava ("slab" or "table land") flows close to the surface (140-150 cm), but the depth of wetting remains the same. A comparatively small amount of moisture is also expended through evaporation of water in these soils, and considerably less is lost through transpiration than under a larch forest, because the young and sparse (thin) forest stand of birch consumes noticeably less moisture than a 180-200 year old larch. Therefore, the moisture of the upper soil horizons of Experimental Plot No. 2 is considerably greater than in Experimental Plot No. 1.

Compared with a larch forest, the soil on a 1960 cutting (Experimental Plot No. 3) expends even less moisture. The content of fall moisture (1960) of the soil on this plot in a 10-50 cm layer slightly exceeded the spring moisture, whereas in the soil of Experimental Plot No. 1 fall moisture was less than the amount in spring. The absolute amount of all moisture of soil of the cutting was greater than that of a larch forest

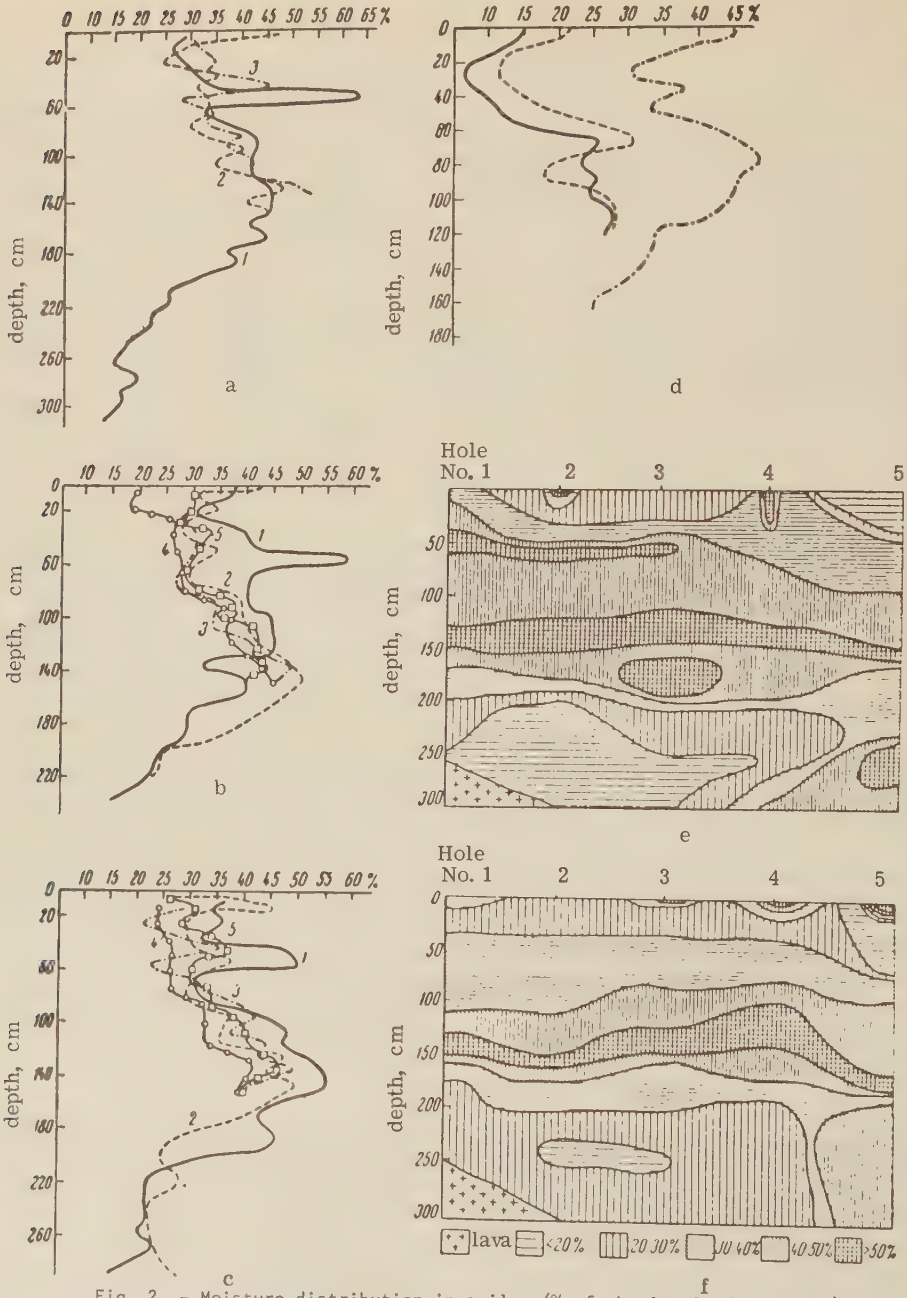

Fig. 2. - Moisture distribution in soils, (% of absolutely dry weight).

a - on cutting area (Experimental Plot 3); 1 - June 5; 2 - September 21; 3 - field moisture capacity; b - beneath birch stand (Experimental Plot 12); 1 - June 16; 2 - July 6; 3 - July 23; 4 - August 17; 5 - September 21; c - in aspen stand (Experimental Plot 11); 1 - June 15; 2 - July 6; 3 - July 23; 4 - August 17; 5 - September 21; d - beneath various types of larch forests (September 2-September 20, 1959): 1 - wild rosemary; 2 - herbaceous; 3 - herbaceous, on left bank of Kamchatka River; e - f - moisture topoisopleths throughout the Sukhaya River-Station profile: e - June 11; f - July 13, 1960.

and even exceeded somewhat the moisture of field moisture capacity (Fig. 2a). The content of fall moisture maximum at a depth of 130-140 cm also increased as compared with the spring maximum, whereas in a larch forest the content of fall maximum decreased during the growing period. Obviously moisture from a 120-150 cm layer in the soil of a larch forest is partially expended through transpiration and, when there are large moisture amounts in the deep layers, the plant does not suffer from stunted growth, even when summer precipitation is inadequate.

A change in the moisture content of soil beneath a birch stand is similar to that beneath a larch forest, the only differences being in the quantitative values. With spring contents of moisture present, the soil of a birch stand dries up considerably less in summer than does the soil of a larch forest, and the soil moisture content approaches the moisture content of the soil of Experimental Plot No. 2 (Fig. 2b). Here we see an increase in soil moisture content in the fall, an increase in the lower moisture maximum, and a shift of the maximum (as a result of moisture flow) from the 100-130 cm layer to the 130-150 cm layer.

Similar moisture content changes are recorded in the soils of an aspen stand (Fig. 2c). Compared with a larch forest and birch stand, an even smaller loss of moisture is characteristic of these soils. At the start of the growing period we note also a temporary moisture maximum above the frozen layer. A relatively large quantity of water is conserved in this layer until August. Fall precipitation again increases the moisture content in the layer and creates a new maximum at a depth of 40 cm. Apparently the fall moisture, to some extent peculiar to all soils, results in the 30-50 cm layer having excess moisture in winter, which explains why the layer thaws out slowly in the spring and why there is poor water permeability in a frozen state.

Thus, by moisture consumption, these items may be arranged as follows (in decreasing order): shrub-grass larch forest > birch stand > 1942 cutting (overgrown with birch) > aspen stand > 1960 cutting.

These patterns of moisture distribution detected in the soil profile are observed also in other types of larch forests, which is confirmed by V. V. Stefin's observations made apparently during the period of maximum soil drying (Fig. 2d). We note an increase of moisture content in these soils at a somewhat lesser depth (60-120 cm), but the increase is clearly seen and serves as proof of an identical depth of wetting of the soils by spring waters. Maximum drying, almost to the point of wilting moisture, occurs in the 10-40 cm layer of soil beneath a wild rosemary larch forest. This type of forest, most widespread in the Central Kamchatka River valley, usually covers well-drained areas.

We must point out that our single observations are preliminary, and that the question of a varying water consumption in the different types of larch forests remains unanswered, although an approximate general pattern can be seen.

The large amount of moisture in the lower part of the soil profile (100-180 cm) has enabled us to assume that soil moisture content are partly replenished by condensation, and partly by the influx of water from the Kozyrevskaya Sukhaya River. However, an experiment with condensation conducted at the end of August 1959 revealed (Fig. 1f) that, in any case, no noticeable movement of water vapor takes place in the surface layers and that water condensation from the air is very little and does not play an important role. No difference in change of amount of water in the soil was observed either when air continuously passed through a soil sample of indisturbed structure, or when a soil sample was isolated from the lower-lying layers of soil.

The results of studying the effect of the Sukhaya River on the moisture content of the lower soil layers of Experimental Plot No. 1 are given in Figures 2e and f. Moisture distribution in the soil throughout the Sukhaya River — Experimental Plot No. 1 profile at the beginning of summer (July 11, 1960) when the melted snows had not yet penetrated, revealed that there are no fundamental differences in soil moisture, except at holes No. 4 and 5, where from above to 60-100 cm we find the alluvium of the Sukhaya River. In the remaining part of the profile moisture distribution by depth coincides with moisture distribution in the soils of experimental plots No. 1, 2, and others. No influence of the Sukhaya River was detected at this period. Following the spring flood, when the water ran from the mountains along the river (the Ploskaya volcano), a repeated determination of soil moisture was made on July 13, immediately after the water subsided. Owing to the excellent water permeability of the soil and alluvium of the Sukhaya River, the water, after having travelled the river bed, wetted the layer lying directly beneath the river bed. No water was observed spreading in any direction during this period. The water literally "disappeared" or "dropped" into the lower-lying layers. The hypothesis that the water of the Sukhaya River moved into the lower layers of the soil of Experimental Plot No. 1, as stated earlier (3), was not proven. Now we can quite assuredly state that the great amount of moisture in the forest soils of the Kozyrevskoye Forest Reserve is the result simply of the high moisture capacity of these soils, their capacity to assimilate well the snow waters and rains, and to hold and conserve moisture from flowing into deep (below 3m) layers and from evaporating. This latter factor, as pointed out previously, was explained by the coarse textured soil, presence of forest floor and "peaty" layer and stratification of the soils.

Characteristics of Water Consumption by Plants

An analysis of the change in moisture contents in soils (Table 5) reveals that in the winter of 1959-1960 moisture contents increased by 149.4-246 mm. During the growing period the amount of moisture lost from the soil differed considerably under various types of forest. The minimum moisture loss was recorded on the 1960 cutting where the contents in spring and fall were almost equal. In addition, we see a redistribution and flow of moisture from the 50-100 cm layer into the 100-150 cm layer. Fall rains (in August and September precipitation was 120 cm) increased the moisture of the upper layers (0-50cm). During the summer water was lost through evaporation from the soil of the clearing area (up to 128.8 mm). Maximum drying of soil was recorded in the middle of August. Thus in soils of a larch forest (taking into account precipitation) 173 mm was expended from the 0-50 cm layer, 51.1 mm from

Table 5

Moisture contents, mm

Depth, cm	23.VIII	13.IX	1.X	4.VI	1.VII	23.VII	17.VIII	21.IX
	1959			1960				
Shrub-grass larch forest, Experimental Plot No. 1								
0–50	52,0	44,9	54,6	167,8	88,5	120,0	72,2	102,2
50–100	95,5	88,9	88,4	157,1	123,0	111,0	106,0	119,6
100–150	182,7	181,2	185,8	249,1	232,4	203,6	199,2	189,2
0–100	142,5	133,8	143,0	324,9	211,5	231,0	178,2	221,8
0–150	330,2	315,0	328,9	574,0	443,9	434,6	377,4	411,0
1942 cutting, Experimental Plot No. 2								
	23.VIII	13.IX 1959	11.X	1.VI	1.VII	23.VII 1960	17.VIII	21.IX
0–50	68,7	98,3	84,5	172,1	109,1	112,3	97,3	113,6
50–100	120,2	125,0	127,4	152,5	142,0	148,0	140,0	138,0
100–150	205,9	191,3	187,1	223,9	256,4	201,3	244,9	213,6
0–100	188,9	223,3	211,9	324,6	251,1	260,3	237,2	251,6
0–150	394,9	414,7	399,1	548,5	507,5	461,6	482,2	465,2
Birch stand, 1960								
	—	—	—	15.VI	6.VII	23.VII	17.VIII	21.IX
0–50	—	—	—	144,4	123,5	113,5	88,7	119,0
50–100	—	—	—	191,6	133,0	121,0	120,0	130,0
100–150	—	—	—	206,2	211,8	223,6	210,2	215,0
0–100	—	—	—	336,0	256,5	234,5	208,7	249,0
0–150	—	—	—	542,2	468,3	468,1	418,9	464,9
Aspen Stand, 1960								
	—	—	—	16.VI	6.VII	23.VII	17.VIII	21.IX
0–50	—	—	—	131,5	135,6	141,8	95,4	121,4
50–100	—	—	—	141,5	135,0	134,0	115,0	127,0
100–150	—	—	—	268,8	225,7	220,4	195,9	217,8
0–100	—	—	—	273,0	270,6	275,8	210,4	248,4
0–150	—	—	—	541,8	496,3	495,2	406,3	466,2
1960 cutting								
	Wilting moist. 1,5 mg	Field moist. capacity	—	4.VI 1960	—	—	—	21.IX 1960 r.
0–50	32,6	130,0	—	126,6	—	—	—	136,6
50–100	27,3	162,0	—	178,5	—	—	—	138,1
100–150	47,3	217,0	—	230,9	—	—	—	249,0
0–100	59,9	292,0	—	305,1	—	—	—	274,7
0–150	107,2	509,0	—	536,0	—	—	—	523,7
Larch isolated in 1960								
	—	—	—	4.VI	7.VII	25.VII	19.VIII	21.IX
0–50	—	—	—	167,8	118,3	106,4	87,5	110,2
50–100	—	—	—	157,1	125,0	122,0	100,6	125,0
100–150	—	—	—	324,9	243,3	228,4	188,1	135,2
Birch isolated in 1960								
	—	—	—	4.VI	7.VII	25.VII	19.VIII	21.IX
0–50	—	—	—	167,8	119,3	132,8	107,4	121,4
50–100	—	—	—	157,1	134,0	126,2	127,5	120,6
100–150	—	—	—	324,9	253,3	259,0	234,9	242,0

NOTE: Precipitation -- August 1959 -- 19.8 mm; June 1960 -- 9.1 mm; July 1960 -- from July 3 to July 6 -- 21.5 mm; from July 6 to July 23-33. 4 mm; from July 23 to July 31 -- 11. 7 mm; August 1960 -- from August 17-32.2 mm; from August 17 to September 21, 1960 -- 50.9 mm.

Note: Comma represents decimal point.

the 50-100 cm layer, and 49.9 mm from the 100-150 mm layer. Precipitation in September was 50.9 mm, of which 16.9 mm evaporated. The total amount of moisture expended during the growing period from the 0-150 cm layer is 290 mm. If we consider that on the 1960 cutting the amount of moisture expended equals 128 mm, the approximate amount lost through transpiration in larch will be 162 mm. Similar calculations reveal that from soils of a birch stand and the 1942 cutting the amount of moisture lost through transpiration was 83-77 mm, i. e., considerably less than in the soils of a shrub-grass larch forest. However, this value is somewhat conditional, because it has been assumed that losses through physical evaporation in soils of a fresh cutting did not increase. We may assume that this is close to the truth, because the litter on soils of a cut-over area was intact (logging occurred in snow), whereby evaporation was made difficult with a negligible increase in evaporation.

In order to estimate more accurately the amount of moisture expended by various species of trees an experiment was set up with separate birch (120 years old) and larch (220 years old) trees, dug along the border of the crown projection to a depth of 100 cm and covered with tar paper. On experimental plot No. 1 the trees were spaced 30 meters apart. The determination of the amount of moisture expended by these two trees reveals that beneath larch moisture loss equals 189.7 mm, while under birch moisture loss is 82.9 mm, that is, these data confirm the amounts of moisture loss determined beneath an undisturbed forest stand. In soils of an aspen stand the amount of moisture lost is almost equal to the amount of moisture expended in birch stands or somewhat less (75.6 mm). Thus, by amount of moisture expended, the foregoing cited sequence of shrub-grass larch stand > birch stand > aspen stand > cut-over area — hold true.

On a whole, the water regime of these soils approaches the type of water regime seen in certain soils of Central Siberia. Yerokhina (6) describes soils where seasonal freezing also creates a temporary excess moisture condition in the upper horizons. However, the water regime of the soils we examined cannot be identified with the water regime of her soils. The principal difference in the soils of Central Kamchatka is the absence of a leaching type of water regime in the sense established by Vysotskiy and developed by Rode (13). In these soils there is no complete wetting, because the small amount of precipitation with a high field moisture capacity is not capable of wetting the entire soil layer down to the ground waters, lying as a rule, at a depth of 8-10 cm and below. In addition, the ground waters are separated by a "slab" — a layer of lava — from the above-lying soil layer. However, the precipitation, having percolated to a depth of 110-180 cm, is actually no longer capable of capillary rise into the upper layers of soil, and therefore all products being leached by it from the upper soil horizons should be accumulated at this depth.

Seasonal freezing, preserved during May-June at a depth of 40-60 cm, plays an important role in improving the water supply of trees. By inhibiting the rapid flow of water into the lower horizons, seasonal freezing thereby improves plant water supply in the zone within the root layer — the zone of maximum soil heating. During the middle of the summer, after the soils have completely thawed out and soil temperature has increased at a depth of 60-100 cm, plant roots begin to utilize the moisture even at this depth. The frozen layer, by preventing deep spring wetting of soils and the downward percolation of water, will create conditions conducive to the slow flow of water into the deep layers of the soil during the summer, and to excellent use of water by woody vegetation. The water regime of the soils of the Kozyrevskoye Forest Reserve differs somewhat from other types of water regime described by A. A. Rode. Thus, in contrast to the percolation type of water regime we see in our soils the absence of complete wetting and the discharging of water to ground flow. As regards the coarse texture of the soils and the clearly expressed stratification, we do not observe in our soils any noticeable capillary rise of water into the upper horizons.

The high porosity of the soils is responsible for their high field moisture capacity and determines the large amount of capillary-suspended moisture. The presence of a layer of long-lasting seasonal freezing, which has in the frozen state a very low water permeability, results in the retention of melted snows in the upper part of the soil profile and is conducive to the development of plants. In this case the role of seasonal freezing is similar to the role of permafrost in the more northern and cold regions. The "Jamin chains" created in a layer of frozen soil are, it seems, one of the principal factors determining the poor water permeability of a frozen horizon (layer).

Thus, an analysis of the data obtained reveals that the soils of the Kozyrevskoye Forest Reserve are characterized by a unique seasonal freezing subtype of water regime — a treatment with capillary suspended moisture.

Seasonal freezing plays a positive role in plant water supply, because, by retaining the moisture of winter precipitation in the upper layers of soil (0-50 cm), it enables trees to utilize this moisture for transpiration at the beginning of the growing period. At the same time, seasonal freezing, although it delays the start of spring root activity, does not decrease root development (5, 11). Therefore, the water, which has percolated into the lower horizons of soil (130-180 cm), is being used partly by trees.

The water-physical properties of the soil are conducive to plants. A high moisture capacity and a somewhat small content of unavailable moisture in the soils are responsible for the wide range of active (productive) moisture. As a result, despite a negligible amount of annual precipitation (~ 400 mm) 60%-70% of which occurs in winter, the plants do not experience any visible signs of stunted growth. An analysis of soil moisture shows that there are always sufficient amounts of available moisture in the soils.

High porosity of soils, on the one hand, is a favorable property, because it is responsible for the soil's high moisture capacity, water permeability, and large number of aerated pores. But, on the other hand, when porosity is high, soils are loose, tree stability decreases, and windfall tendencies increase; it is possible that with such high porosity there is a decreased interaction between young tree sprouts and seeds, on the one hand, and soil, on the other, and the absorption from the soil of water and nutrient substances is made difficult; and this probably decreases in some measure the regeneration of trees, from seeds.

The stratification of the profile makes the capillary rise of water toward the surface of the soils difficult; in addition, evaporation of water from the soil decreases, which favors excellent use of water by plants.

In amount of moisture lost (through transpiration) first place belongs to larch forest followed by birch, then aspen with the least amount of water expended in a recently cut-over area. On an average, larch consumes 160-190 mm, birch 77-83 mm, and an aspen stand 76 mm/ha of moisture.

Water contents in soils are replenished only by atmospheric precipitation; in addition, the water is obtained principally from the melting of snow and from the intake into the soil of these melted snows. There is practically no influx of water from numerous streams and rivers because, as a result of the extreme high water permeability of the soils, excess water percolates directly under the river bed and into the ground waters flowing beneath the lava.

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TYPOMORPHIC NEOFORMATIONS IN QUATERNARY DEPOSITS OF THE USSR DESERT BELT

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Neoformations are a characteristic manifestation of supergene processes. The geochemical landscape of these processes in any given region is nicely reflected in the composition and structure of these formations. Polynov (19) was among the first to draw attention to the necessity for studying them in detail with the aid of up-to-date methods of mineralogical chemical investigation.

The study of neoformations in the youngest (Quaternary) deposits, where supergene transformations started relatively recently and is still going on, is of particular interest. There is now a great deal of evidence to show that definite typomorphic neoformations correspond to a definite landscape. This explains the remarkable phenomenon of "zonality in the mineral kingdom" established by Dokuchayev at the end of last century (8).

This paper describes neogenesis of Quaternary deposits in subtropical deserts. As a starting point we have taken data from field observations and the results of experimental research on aspects of the USSR desert belt's geochemical landscape. The author has worked for several years in various parts of Central Asia and Kazakhstan (the Kazakh hummock area; the Chu-Ili mountains and the eastern part of Bet-Pak-Dal, the Central Kyzyl-Kumy, the Trans-Unguz Kara-Kumy, Ustyurt and Western Transcaspia), studying the conditions under which neoformation occurs and collecting typical samples which were then subjected to detailed mineral-logical-geochemical and micro-morphological analysis.

The desert and semi-desert lands in the subtropical belt of the northern hemisphere have had a complicated history. Major geochemical research on the Soviet deserts has been done by Fersman (30, 31), Kovda (11, 12), Perel'man (16, 17, 18), Sidorenko (27, 28) and others.

Repeated flooding has been a particularly important feature in the formation of the desert lands. Traces of the violent activity of water, astonishing in the contrasts they cause in the desert landscape, bear witness to the changing conditions under which supergene processes have occurred throughout Pliocene and Quaternary times.

An important geochemical feature of the deserts, established by Perel'man (17), is that the effects of earlier supergene processes have been preserved: the Quaternary deposits in the deserts contain not only neoformations which have come into existence under modern (or similar in point of geochemical topography) conditions but also those formed under conditions of intensive flooding.

The two main groups of supergene neogenesis found in these regions are therefore described separately.

Neoformations Formed Under Contemporary or Similar to Contemporary Geochemical Landscape Conditions

Carbonate neoformations. These are very characteristic both of eluvial and of excessively wet desert landscape. In relatively thick loess-like deposits, and in particular in the proluvial type, the commonest form of neoformations are mealy accumulations of loess with white nodules, usually less than 1 cm in diameter. More rarely, these conditions give rise to compact concretions (lime nodules) with extremely irregular but completely isometric outlines (Fig. 1a). Lime nodules, however, are particularly typical of the loess and loess-like proluvial framework of the Tien Shan ridges. Several horizons of such neoformations can often be distinguished in the thick loess strata of the foothills. The phenomenon is widely developed throughout the arid zone of loess and loess-like deposits (15, 37).

In the shallow mantle deposits of rock debris widely developed on old low-mountain desert massifs (the Chu-Ili mountains; Bukin-Tau, Altin-Tau and other massifs in the central part of the Kysyl-Kumy) carbonate grooves developed on the bottom part of fragments of the parent rock are highly typical (Fig. 1b).

Neoformations of carbonates are not chacteristic of sandy desert. They are found only where the sands are fixed in place; fine, loose incrustations, consisting of sands cemented by neogenetic carbonate, occur on the surface of dunes. Neoformations of carbonates do not occur in winnowed sand.

Such formations occur in excessively wet lands where there is calcium bicarbonate of of mineralized waters. Unusual forms, consisting of peculiar gray or brown mantles, occur in lacustrine clays near the roots of the common reed *Phragmites communis*, which grows extensively along the lower periphery of lakes (Fig. 1c).

Microscopic study of thin sections of neoformations of carbonate reveals that the neogenetic carbonate is invariably fine-grained and cryptocrystalline in structure. Individual crystals are rarely bigger than 0.05 mm in diameter and only the largest grains reach a diameter of 0.01 mm. The neoformations contain not only cryptocrystalline carbonate but also particles of parent rock — grains of clastic minerals (mainly quartz) and very small particles of an unidentified pelitic substance. The proportion of these inclusions varies greatly.

Neoformations of carbonates, as a rule, have a more or less pronounced metacolloidal micro-structure, particularly in line nodules and grooves (Fig. 1d).

The relative proportions of neoformations of carbonates to parent rock indicate, even on visual examination, that metasomatic processes have accompanied their formation. This hypothesis is confirmed by the microscopic data. Quaternary clay minerals, represented mainly by minerals of the hydromica family, are found in small amounts and clastic minerals predominate. Finely, dispersed clay minerals are apparently broken down in the course of neoformation, whereas clastic minerals prove resistant to supergene effects. In many cases, however, it can be seen that the neoformations of carbonates are corroding and even metasomatically replacing silicates of magmatic origin (Fig. 1e). Carbonate supergene metasomatism may be a characteristic process in the formation of a certain type of weathering crust (calcareous orthoeluvium) (20).

Immersion determination of the refractive index of several dozen samples of neoformations of carbonate showed that Nm varied between 1.658 and 1.662 (that is, within the limits of measurement accuracy, ± 0.003). The crystal optic data indicate an almost purely calcite composition. Where matasomatic effects are present this calcitic composition

Table 1

Rational Analysis of Neoformations of Carbonates

Component	Analysis results, % weight			As percentage of neogenetic matter		
	I[a]	II	III	I	II	III
			Sample in original form			
CO_2	22,66	30,42	37,58	37,35	41,60	39,53
$H_2O_{105°}$	1,82	3,60	0,38	Excluded from calculation		
$H_2O_{180°}$	0,54	0,40	0,36	0,21	0,54	0,37
			10% Na_2CO_3 extract			
SiO_2	0,21	0,17	0,33	0,35	0,23	0,34
TiO_2				—	—	—
Fe_2O_3	0,04	0,06	0,11	0,06	0,08	0,11
Al_2O_3	0,01	0,17	0,67	0,02	0,23	0,70
			10% HCl extract			
SiO_2	0,94	0,69	0,68	1,59	0,94	0,71
TiO_2	0,01	Traces		0,02	Traces	
Al_2O_3	2,04	1,00	0,86	3,03	1,35	0,90
Fe_2O_3	0,98	0,51	0,44	1,66	0,69	0,46
CaO	26,56	37,62	51,85	43,95	51,41	54,62
MgO	1,81	1,07	1,39	3,23	1,45	1,45
SrO	0,28	0,31	0,14	0,47	0,42	0,14
Na_2O+K_2O	0,79	Not det'd.		1,33	—	—
			10% Na_2CO_3 extract			
SiO_2	3,58	0,78	0,64	0,06	1,06	0,67
Insoluble after extraction of residues	38,67	21,68	3,66	Excluded from calculation		
Total	99,57	98,88	99,33	100,00	100,00	100,00
Total of free SiO_2	4,73	1,64	1,65	8,00	2,23	1,72

[a] I — friable nodules; II — compact concretions; III — collomorphic coatings.

Note: Comma represents decimal point.

of the neogenetic carbonates is particularly interesting.

Part of the chemical elements caused to migrate as a result of supergene effects accumulate in the ground waters; hence a certain increase in the silica content of desert ground waters. Part goes to form new minerals, mainly secondary hydrous silicates. These minerals, often of a bright yellow or greenish yellow hue, do not form large aggregations but are geochemically important. A considerable part of the chemical elements appear in their individual state in the neoformations (Table 1).

Rational chemical analysis of neoformations of carbonates reveals a very low magnesium content. A number of chemical elements (silica, aluminum and others) which do not form part of the crystal lattice of the carbonates, can be detected in the composition of the newly-formed matter (Na_2CO_3 and HCl extracts). This means that not only are these elements not present in the form of an isomorphic admixture in the calcite, but also do not enter into the composition of the clastic minerals, which pass out as an insoluble residue. The state of these elements is not clear. It may be assumed that they have been taken up by the neoformations of carbonate as a result of colloidal and metasomatic effects.

Here, it seems, is the explanation for the large number of small elements contained in these neoformations (Table 2); all the small elements contained in the Quaternary deposits are found in them, albeit in small amount. The exception is strontium, of which the content in the neoformations of carbonates is greater in the series than in the Quaternary deposits.

The Sr:Ba ratio in the neoformations of carbonates is of great interest, for it responds sensitively to the degree of aridity of the country. In newly-formed forest steppe this ratio is unity or approximate unity and becomes greater the further south one goes. In the neoformations of South Kazakhstan it is 7.

Neoformations of gypsum the commonest and most characteristic neoformation of the desert is gypsum. With this in view, the great authority

Table 2

Average content of minor elements in supergene neoformations (in 1.10^3%)

Element	Sensitivity of determination	Carbonates	Gypsum		Chloride-sulfate	
		a[1]	b	c	d	e
		Number of samples				
		18	6	8	15	4
Ti	1	90	28	10	1,3	6,8
Mn	1	38	7,5	4,3	1,1[a]	7,0
Ni	1	1,3	0,5[b]	Not det'd.		0,5[b]
Co	1	0,9[a]	0,5[b]	"		Not det'd.
V	1	5,8	1	1,3	0,8	1,0[a]
Zr	1	4,8[a]	1,4	0,6[a]	0,8[b]	1,0[a]
Cu	1	4,6	1,4[b]	0,5	1,0[a]	1,0[b]
Mo	1	0,5	Not det'd.		1,8[a]	0,5[b]
Ag	1	0,5[b]	0,5[b]	Not det'd.	0,5[b]	Not det'd.
Ga	1	2,5	1,0	0,5[b]	1,0[b]	1,0[a]
Sn	1	0,5[b]	Not det'd.			
Yb	1	1,1[a]				
Sr	50	272	308	333	50[a]	50[b]
Ba	50	37	12[b]	10[b]	10[b]	Not det'd.
Li	100	55[b]		Not det'd.		
Cr	10	6,4	5[b]	"		4[b]
Nb	10	Not det'd.	5[b]	"		
Pb	10	8[a]	5[b]	Not det'd.	5[a]	5[b]
Zn	10	5[b]	5[b]	Not det'd.		
Sc	5	5[b]		"		
La	10	5[b]		"		
Y	10	4,7[a]	1[b]	"		
Ce	10	5[b]		"		
Sr:Ba	10	7	25	33		Not det'd.

---

[1] a, b, d — South Kazakhstan; c — West Transcaspia; e — Trans-Unguz Kara Kumy.

[a] Sometimes not detected.

[b] Detected in more than 50% of the samples.

Note: Comma represents decimal point

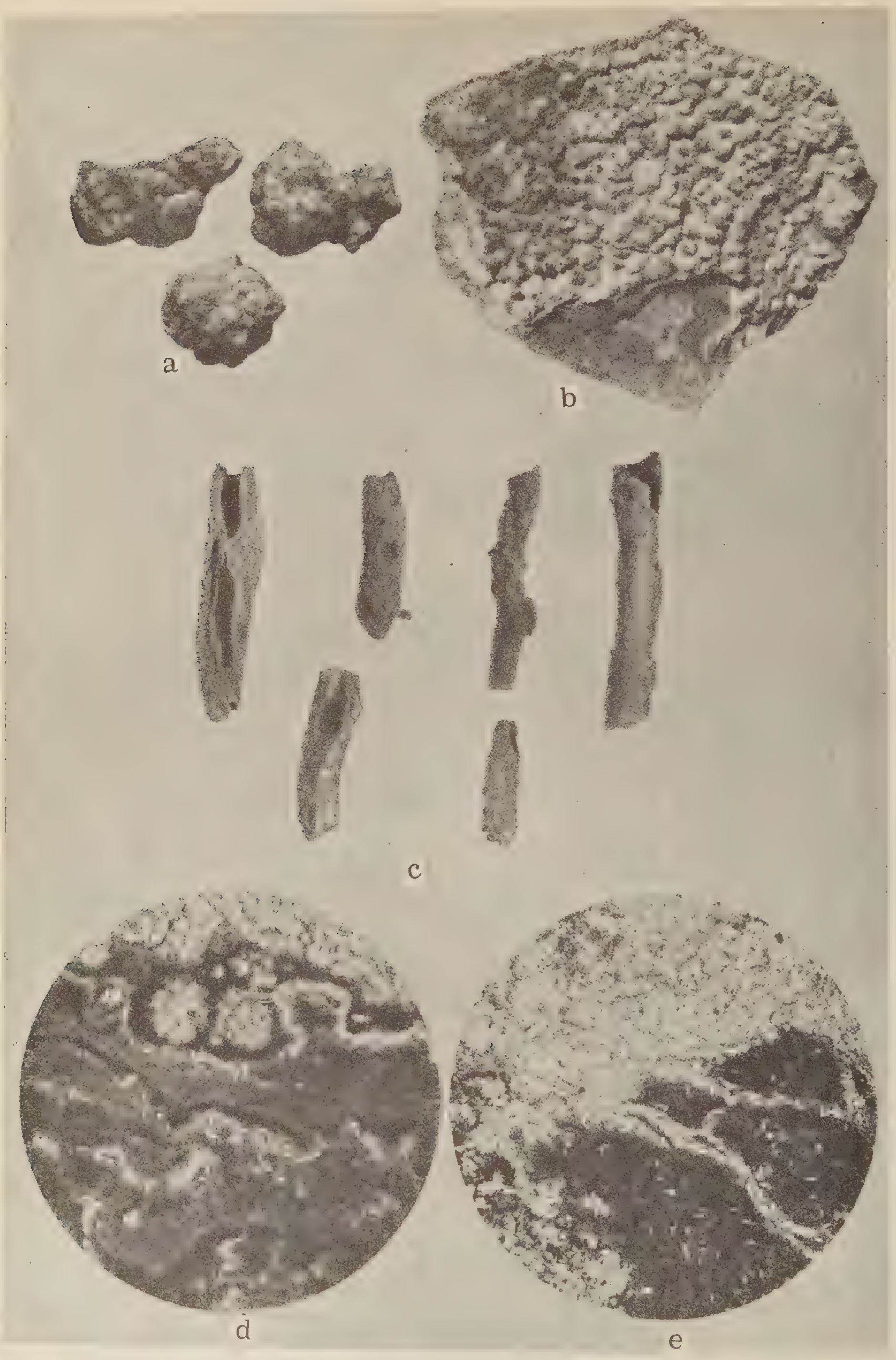

Fig. 1. - Neoformations of carbonates.

a - Lime nodules from loess deposits in proluvial train, Zeravshan Range. X 2; b - collomorphic crust-groove on fragment rock, Chu Ili mountains; c - tubular concretions from lacustrine deposits, South Balkhash; d - metacolloidal microstructure of neoformations of carbonate, X 250. Parallel nicols; 3 - replacement of felspar phenocrystal (black) by neogenetic carbonate (light) at contact between grooves and felsitic porphyry debris. X 200. Crossed nicols.

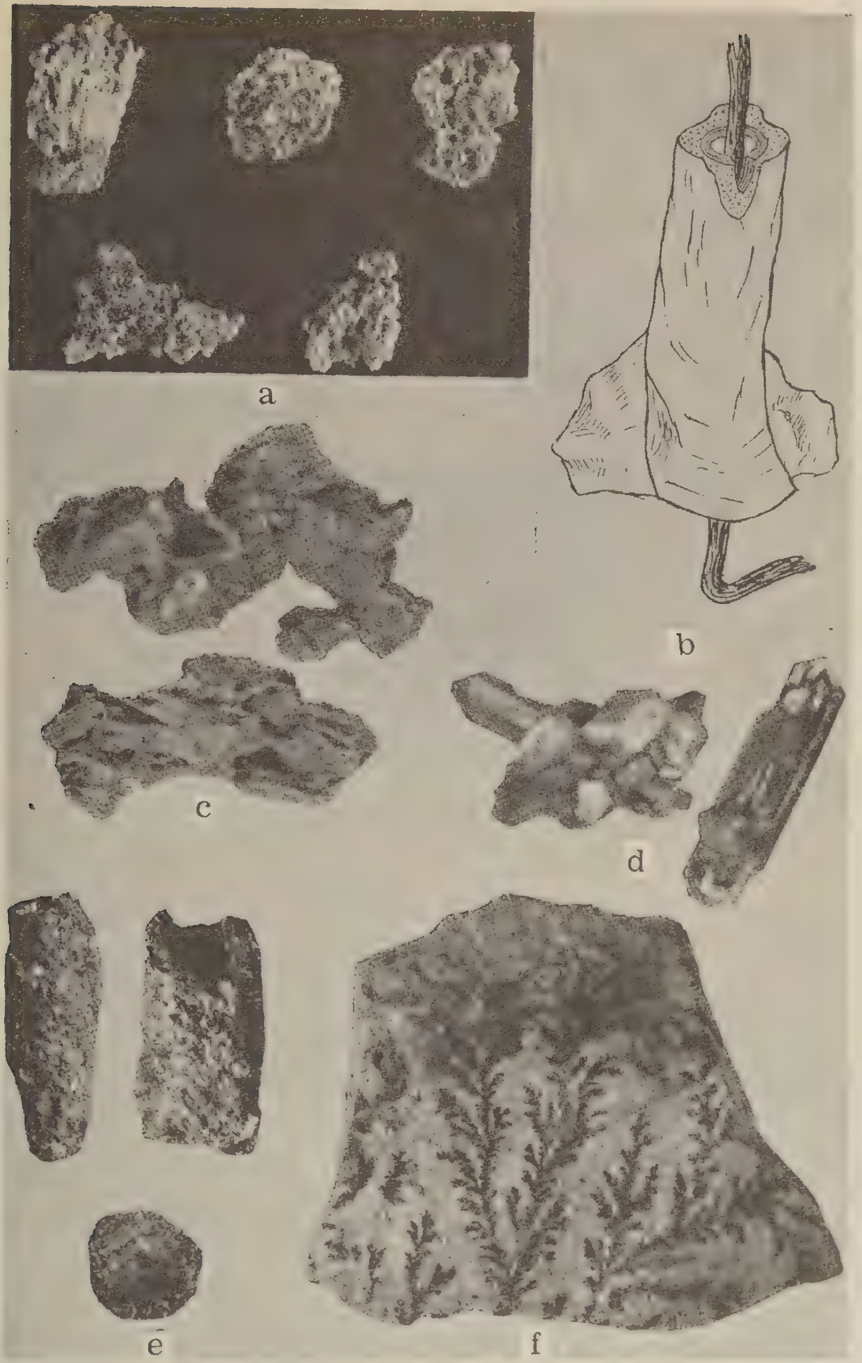

Fig. 2. - Sulfate and manganese neoformations.

a - friable gypsum concretions from top of mantle deposits, Chu-Ily mountains. X 1.8; b - gypsum mantle (akkyrsh) near dead haloxylon root, South Kazakhstan, c - gypsum concretions from bottom part of mantle deposits, Chu-Ily mountains; d - mirabilite crystal and crystal druse, South Balkhash; e - tubular and circular nodules of iron hydroxides from buried meadow soil, Chu valley. X 8; f - dendrites of manganese hydroxides on rocky surface, Bet-Pak-Dal.

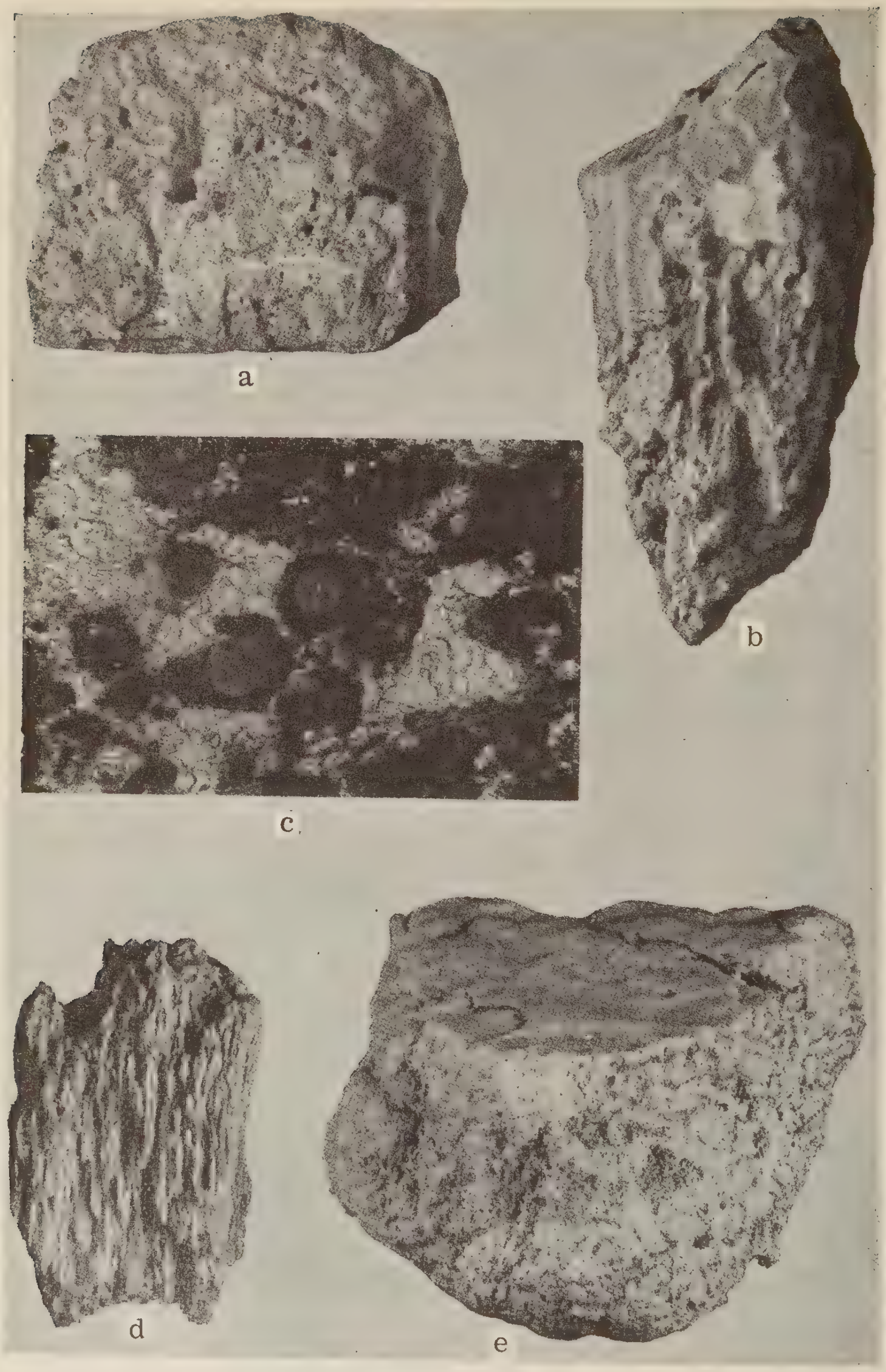

Fig. 3. - Relict neoformations.

a - lump of massive carbonate neoformations of caliche type. Chu-Ily mountains; b - icicle-like concretion from calcareous crust, Near East; c - collomorph formations in calcareous crust, Near East. Light shading - late generation neogenetic calcite; d - lump of columnar gypsum, Chu-Ily mountains, e - lump of Near East gypsum crust.

on supergene mineralogy, Samoylov (23), points out that "a detailed description of the desert gypsums would undoubtedly be one of the most instructive chapters in desert mineralogy".

Under eluvial conditions a large amount of finely-crystalline dispersed gypsum forms at the bottom of the profile of gray-brown soil on loess-like deposits and loesses. The crystals have an isometric, pseudo-bipyramidal habit, owing to the predominance of faces of the form {110} and {111}; faces of the form {010} are moderately developed. These crystals are usually 0. 1 to 1. 0 mm in diameter and rarely as much as 2 mm. Fine-grained gypsum often forms micro-concretions measuring 2-5 mm in diameter with an irregular spherical shape. Larger (up to 2-3 cm in diameter), friable nodules also occur (Fig. 2 a). In some parts of the slopes of proluvial deposits the amount of small-grained gypsum is so great that the top part of the Quaternary deposits turns into a tuff-like friable porous mass up to 1-2 cm thick.

Fine-grained mealy gypsum often forms loose cover known as akkyrshi around halxylon roots (Fig. 2b and 26).

In the shallow detrital mantle deposits of monadnocks and old massifs newly-formed gypsum is present in the form of grooved overgrowths on fragments. Here the shape of the gypsum crystals is prismatic and fine-platey.

In sandy deposits neoformations of gypsum occur only where there are ground waters in the immediate vicinity. Under these conditions large crystals and druses of gypsum form, often merging into compact horizons. The newly-formed gypsum crystals form a poikilitic cement for the sands. Neoformations of this type have been known as Repetek gypsums, after the railway station and national forest of Repetek, where they are particularly in evidence.

Such neoformations were first studied by Dokuchayev (9), who established that they formed as a result of the evaporation of nearby ground waters inside the subsoil. Proportions between 34% and 61% of gypsum proper have been detected in the chemical composition of Repetek gypsum crystals. The remainder of the crystal consists of particles of parent rock, mainly quartz and felspathic sandstones. There is some admixture of calcium carbonates and a minute amount of chlorides.

The Repetek gypsums have been investigated by the well-known crystallographer Yeremeyev (10), who has established that the faces of forms {111} {010} are the most developed and those of the forms {120} and {110} being less in evidence. Twins with the composition face along the first pinacoid are very common. This so-called (Hallé) twinning law is characteristic also of supergene gypsums from Quaternary deposits in more northerly parts of the arid zone (5). Gypsums of the Repetek type often form unusual fan-shaped or disc-like nodules of twinned crystals measuring up to 10-20 cm in diameter. Such neoformations are particularly characteristic of sandy terraces in the large drainless depressions of Transcaspia (Karagiye and others).

Gypsum neoformations, although best known in relation to excessively wet sandy lands (Repetek gypsums), are also commonly found in clay-loam deposits, where they form small-crystalline concretions and minor intercalations.

Under the microscope gypsum neoformations are seen to be well-formed transparent crystals containing a comparatively small number of particles captured from the parent rock. The micro-structure is usually equigranular, often druse-like. No relicts of colloidal or metasomatic effects have been detected.

The refractive indixes of newly-formed gypsum are: Ng' = 1. 526-1. 529 (+ 0. 003); Np' = 1. 519-1. 520 (± 0. 003); Ng' - Np' = 0. 009. Dispersion of the refractive indixes is often observed (0. 006-0. 008; in individual cases this figure may be higher). Dispersion of the optic axes is weak (V > R).

On rational chemical analysis gypsum neoformations are shown to contain a smaller amount of admixtures than carbonate neoformations, despite the considerable content of insoluble residue (Table 3). The content of almost all small elements is lower in the gypsum than in the carbonate neoformations (Table 2). The strontium content is higher. As a result, the Sr:Ba ratio, which is about 5 in the gypsum neoformations from Quaternary deposits in the steppe zone, is 25 in the southern Balkhash region and as much as 40-50 in the Kara Kumy and Ustyurt neoformations.

Sulfate and chloride water-soluble for neoformations. These are genetically closely connected with surface and ground waters and are therefore little characteristic of eluvial desert lands. In watershed areas such neoformations, in the form of salt efflorescences, usually coincide with depressions where surface waters accumulate, or with slopes where surface and drainage waters run dry. In the latter case a peculiar "salt proluvium" forms.

Water-soluble neoformations are less typical of sandy deposits than loess-like or detrital mantle deposits. In the gray-brown soil developed on these deposits, a certain amount of water-soluble neoformation concentrates during the summer on the surface and at the bottommost parts of the profile (in the lower half of the gypsum horizon).

Water-soluble neoformations are abundant and mineralogically varied under excessively wet conditions. Various minerals of this group occur in the bottomlands of river valleys, along the periphery of salt lakes or in the brine of such lakes, in the salt mass of dried-out sors (salina) and in salt bottoms of various origins. The water-soluble neoformations are sulfates and chlorides, with mirabilite, thenardite and halite predominating.

Halite usually forms irregular segregations in the Quaternary strata, coatings, dense films and plates in sors. Plates of native salt are made up of compacted halite crystals with square outlines and a system of vicinals along the

Table 3

Rational analysis of gypsum neoformations

Component	Analysis results, % weight				As percentage of neogenetic matter	
	I[a]	II	III	IV	I	II
Sample in original form						
H_2O	15,44	16,08	19,37	20,23	19,52	20,10
10% HCl extract						
SiO_2	0,59	0,50	Not det'd.		0,74	0,62
TiO_2	Traces		''		Traces	
Al_2O_3	0,20	0,56	''		0,25	0,70
Fe_2O_3	0,26	0,27	''		0,33	0,34
CaO	25,36	26,03	33,16	32,84	32,66	32,66
MgO	0,35	Not det'd.	0,78	0,80	0,44	—
BaO	Not det'd.		Not det'd.		—	—
SO_3	36,69	36,14	45,52	45,34	46,39	45,56
10% Na_2CO_3 extract						
SiO_2	0,21	0,1	Not det'd.		0,26	0,12
Insoluble after extraction of residues	20,50	19,45	1,80	1,73	Excluded from calculatn	
Total	99,60	99,13	100,63	100,94	100,0	100,00
Total of free SiO_2	0,80	0,60	—	—	1,00	0,74

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[a] I -- friable gypsum nodules from top part of mantle Quaternary deposits, South Balkhash; II -- dense concretions from bottom part of mantle Quaternary deposits, South Balkhash; III, IV — fine-grained gypsum from tubular concretions (akkyrshi, Kara Kumy (26)).

Note: Comma represents decimal point.

marked faces of the octaohedron-combination forms {111} and {100}. Along the periphery of individual platelets, "frost-like" patterns often form, consisting mainly of octaohedra growing on a previous crystal along the C-axis or along the {111} face. Where conditions permit, a peculiar crystallization of cubic or, more rarely, octahedral crystals occur, often somewhat prolate along the {111}:{111} edge. Peculiar graded cone-like "inverse" crystals, formed during crystallization under conditions of rapid evaporation, are very characteristic (1).

In an immersion preparation halite is isotropic, with refractive index N = 1.544. Halite predominates among the water-soluble neoformations in the west Transcaspian deserts and certain parts of the Kazhak hummock region.

Mirabilite, which forms in large amounts, is an ephemeral mineral, for it quickly loses water of crystallization and turns into a dehydrated sodium sulfate. It forms large crystals of columnar habit, elongated along the second crystallographic axis to 5-7 cm (Fig. 2d). In the dry desert air these crystals dehydrate within literally a few hours of their formation and are scattered in the form of a fine, white thenardite powder.

Thernardite forms very small (less than 0.01 mm in diameter) soft scales. Accumulations of these, in the form of loose, easily winnowed masses and efflorescences are particularly widespread within the eastern part of the Bet-Pak-Dal plateau and south Balkash region. In this province sodium sulfates are the predominant minerals among the group of water-soluble neoformations. In the West Transcaspian deserts and the central part of the Kyzyl-Kumy, thenardite is necessarily present to a greater or lesser degree among the salt accumulations and efflorescences.

The refractive indexes of sodium sulfate neoformations dehydrated under natural conditions are: $\underline{Ng}' = 1.484$ (± 1.484 (± 0.003); $\underline{Np}' = 1.475$ (± 0.003); $\underline{Ng}' - \underline{Np}' = 0.009$.

Chemical analysis (Table 4) shows that pure neoformations of chloride or sulfate does not occur; only the chloride-sulfate ratio alters.

A number of other minerals have been detected in close paragenesis with halite and thenardite, but in a smaller amount, in the composition of salt neoformations.

Epsomite forms colorless, inclusion-free segregations of irregular shape, measuring

Table 4

Composition of water-soluble neoformations

Component	Analysis results, % weight			
	I[a]	II	III	IV
$H_2O_{105°}$	0,63	0,23	—	0,20
Ca	0,73	0,40	0,40	0,20
Mg	0,24	0,06	0,76	0,68
Na	26,00	30,80	28,80	36,92
K	0,01	0,03	0,03	
SO_4	46,08	64,77	60,50	1,25
Cl	8,70	2,09	3,83	
HCO_3	Not det'd.			0,55
Insoluble after extraction of residues	14,05	0,28	0,61	0,20
Total	96,44	98,66	94,83	98,45

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[a] I — efflorescence of salts on gully bottom, Chu-Ili mountains; II — dehydrated mirabilite crystals of salt lake, South Balkhash; III — salt efflorescences from; IV — Salt accumulation in drainless depression, West Transcaspia.

Note: Comma represents decimal point.

tenths of a millimeter. Measurements on four samples gave the following refractive indixes: Ng' = 1.460 (± 0.003), Np' = 1.433 (± 0.003); Ng' − Np' = 0.027.

Minerals of the astrakhanite group from finely-squamite accumulations. The optic constants of the minerals composing this group varied appreciably from one sample to another (Ng' from 1.466 to 1.481; Np' from 1.433 to 1.476). This is evidently because the minerals of this group are different representatives of the isomorphic series astrakhanite $Na_2Mg(SO_4)_2 \cdot 4H_2O$ — wattevillite $Na_2Ca(SO_4)_2 \cdot 4H_2O$.

Apart from the minerals established by us, saltpeter and glauberite are mentioned in the literature as occurring in the Central Asian salt bottoms (4, 25 and 2, 22 respectively).

In addition to the neogenetic minerals enumerated, which are more or less widespread in the desert belts of the Soviet Union, rarer minerals are occasionally found. These have been detected mainly in the monadnocks of old massifs and form associations with salt efflorescences (atacamite and others, for example).

A noticeably low content of minor elements is characteristic of water-soluble neoformations (Table 2). Examination of dried water-extract residues (6) indicates that the only elements present in large amounts are boron and molybdenum.

Neoformations of iron and manganese. These in general are not characteristic of the desert belt, but under excessively wet conditions the formation of ferrous and sulfurous iron compounds have been observed in a number of cases. Under the geochemical conditions of moist solonchaks, for example, the abundant formation of hydrogen sulfide gives rise to large masses of a black liquid colloidal iron sulfite (melnikovite, hydrotroilite).

In the bottomlands of large rivers conditions of acute oxygen deficiency are often created, entailing the formation of iron oxides. Ferrous oxide phosphates are found under these conditions, according to a personal communication from A. V. Sidorenko. In a gleyed horizon of buried meadow soil in the Chu valley I have found small (2-3 mm in diameter) nodules of iron hydroxides and several larger round and tubular concretions of manganese hydroxides (Fig. 2 e).

It is noteworthy that under desert conditions certain chemical elements, including iron and manganese, are freed as a result of supergene effects in igneous and metamorphic rocks. This leads to the formation of very fine silica-iron films of "desert varnish" and dendrites of manganese hydroxides on the surface of rock fragments (Fig. 2f); but these phenomena are not strictly part of the processes of supergene transformation of the Quaternary deposits.

Relict Neoformations Formed Under Landscape — Geochemical Conditions for Which There are no Direct Analogs Among Present Desert Landscape

The supergene neoformations in the desert belt Quaternary deposits include also some which have not originated in modern times. I am not referring to buried neoformations of modern type, such as the buried lime nodules and gypsum concretion horizons, but to those of a substantially different type, which characteristically occur in Early Quaternary and Pliocene deposits.

Many investigators have studied the relict neoformations of the USSR desert belt. Perel'man (16, 18) and Sidorenko (28) have thrown light on the mineralogy and geochemistry of these unusual formations, and Perel'man has discovered their origin.

Carbonate neoformations. Numerous carbonate neoformations in the form of massive concretions occur in the top part of the Pliocene and Lower Quaternary deposits in the Trans-Unguz and South-east Kara Kumy regions and in many parts of the Kyzyl-Kumy and Badkhyz. Their size, which is sometimes as much as 1 m, their location in relatively coarse clastic deposits and the fact that they are clearly associated with definite stratigraphical horizons distinguish them from the Modern and Late Quaternary neoformations described previously.

They are made up of a somewhat coarser calcite than the cryptocrystalline variety of the loess lime nodules. Relicts of colloidal and metasomatic effects are a common feature in both modern and ancient carbonate neoformations. The chemical composition of the ancient type also has much in common with that of the modern: the large amount of sorbed chemical elements (especially silica) and the distinct predominance of strontium over barium.

The Pliocene and Lower Quaternary Neoformations on the one hand and the modern and Late Quaternary carbonate neoformations on the other, thus have a similar chemical and mineralogical composition and analogous microstructural features, but differ in regard to conditions of bedding, morphology and, in part, size of individual crystals. The conditions under which the old and the modern neoformations came into existence were evidently partly similar and partly different.

According to Perel'man (18) the carbonate nodules are neoformations which originated in the course of Pliocene and Lower Quaternary hydromorphic supergenesis. This was because the territory now occupied by desert formerly consisted largely of excessively wet lands. Several Soviet and foreign investigators (3, 34, 36, 41) have confirmed that the arid subtropics suffered periods of inundation throughout Pliocene-Quaternary times. On the other hand, according to paleographic research, climatic conditions in the desert belt have remained substantially unchanged from Pliocene times to this day.

Intensive flooding under arid climatic conditions seems to have caused vigorous hydromorphic supergenesis, relicts of which have been preserved in the form of thick neoformations, primarily carbonates.

The very wide distribution of such relicts is due to the fact that pluvial epochs occurred in all parts of the arid zone. Apart from the districts enumerated previously, I have observed carbonate neoformations of this type along the western periphery of the Chu-Ily mountains (Fig. 3a). Similar formations are known in the Far East and North Africa as carbonate crusts (32, 39, 40). In Mexico and the south of the USA they are known as caliches

Table 5

Chemical composition of relict carbonate neoformations

Component	Carbonate concretions, Central Asia (18)	Carbonate crust, Syria
H_2O	Not det'd.	0,32
CO_2	36,04	40,16
	5% KOH extract	10% Na_2CO_3 extract
SiO_2	0,32	0,26
Al_2O_3	0,09	0,04
Fe_2O_3	Not det'd.	0,20
	5% KOH extract	
SiO_2	Not det'd.	0,12
TiO_2	"	Not det'd.
Al_2O_3	0,28	0,46
Fe_2O_3	0,71	0,26
MnO	Not det'd.	0,01
CaO	48,50	51,00
MgO	1,00	0,58
Na_2O	Not det'd.	2,22
K_2O	"	0,04
	5% KOH extract	10% Na_2CO_3 extract
SiO_2	4,63	0,23
Insoluble residue	Not det'd.	3,74
Total	91,57	99,72

Note: Comma represents decimal point.

(33). Sidorenko (29), who studied the Mexican caliches, established that these formations were very similar to the relict carbonate neoformations of Central Asia.

I have studied typical samples of the carbonate crusts in the Near East (7). These are either made up of variously-shaped concretions, often of an unusual icicle-like type (Fig. 3b) or form a continuous horizon, from a few centimeters to a meter or more thick. The crusts occur at various hypsometric and erosion levels and are bedded on Neogene and younger deposits. Their lithological composition has no particular significance. They are made up of cryptocrystalline calcite with traces of colloidal effects (Fig. 3c) and contain particles of parent rock. On the whole, they greatly resemble the relict carbonate neoformations of Central Asia; their chemical composition is also very similar (Table 5). The Sr:Ba ratio is about 15.

Epochs of flooding have been accompanied by repeated formation of such crusts. It has been established that there was no close connection between the glaciations of the temperate zone and the innundation epochs of the arid temperate zone and the inundation epochs of the arid zone. Pluvial epochs were due not to the melting of large masses of continental ice but to variations in the general atmospheric circulation from periodic shifts to the high-pressure subtropical region (35). Paleoclimatologists distinguish a number of flood stages in the Near East; similarly, the territory of the USSR desert belt evidently underwent a series of flood stages.

Gypsum neoformations. Relict neoformations of columnar gypsum are to be found over the immense territory of the desert belt from the western border scarp (chink) of the Ustyurt plateau to the eastern end of the Chu-Ily mountains on preserved remnants of the old surfaces. These relicts are intergrowths of finely-prismatic gypsum crystals, abruptly elongated along the third crystallographic axis (Fig. 3a). The crystals are 0. 5-2 mm in diameter and up to 7-8 cm long, with very poorly-expressed faces, owing to the vertical striation and a series of vicinal formations in the zone of the monoclinic prism.

It is not clear why crystals of a type, so unusual in gypsum, should form in such large amounts. All that can be said is that such a crystal habit in gypsum is typical exclusively of the desert belt relict neoformations. Formed as it is on pebbly and detrital deposits, the gypsum takes on the shape of grooved growths. Sometimes the columnar shape of the newly-formed gypsum becomes less pronounced and the mineral then acquires a spongy structure. Even then, finely-prismatic crystals predominate.

Refringence in columnar gypsum is normal. Some rise in the dispersion of the refractive indixes (of the order of 0. 008-0. 010) is often observed.

Columnar gypsum contains a variable amount of finely-clastic particles of parent rock and silt captured during crystallization.

The thickness of the columnar gypsum horizon varies, depending on the conditions of its formation and on erosion processes. It varies from a few meters on the Ustyurt plateau to the eroded residues of this horizon, about 10 cm thick, in the Chu-Ili mountain area.

Columnar gypsum sometimes grow on carbonate concretions. The neoformations presumably date from late stages of the pluvial epochs. In many regions the gypsum neoformation relicts are not accompanied by carbonate neoformations. In the central part of the Ustyurt plateau, for example, the latter are not found, despite the regional distribution of the columnar gypsum horizon. In Polynov's opinion (21) this is due to the peculiar past history of the Ustyurt landscape which formed a depression after the withdrawal of the Sarmatian sea, where supergene processes occurred under conditions of intensive salt accumulation. As Perel'man has established (18), the formation of columnar gypsum occurred under excessively wet topographical conditions but, unlike that of the carbonate neoformations, under conditions of intensive salt accumulation as well (apparently, in a special type of old solonchaks).

Apart from Central Asia, columnar gypsum has developed in the arid parts of Transcaucasia (14) outside the Soviet Union; relict gypsum neoformations are widely distributed in the arid Mediterranean zone in the form of gypsum crusts (32, 38).

The gypsum crusts in North Africa and the Near East are not more than 0. 5-1. 0 m thick. The top of the crust is a compact consistence (Fig. 3 e), the bottom is loose and powdery, gradually giving way to gypsum-enriched rock.

The gypsum crusts are made up of small-crystalline gypsum, containing a small amount of clastic material. The high degree of crystallization, the absence of traces of colloidal materials and the small amount of admixture elements indicate that the neoformations originated in an ionic water medium.

Chemical analysis (Table 6) shows that the relict gypsum neoformations contain small amounts of chemical elements which do not enter into the gypsum crystal lattice. The Sr:Ba ratio is about 50.

Celestite neoformations. The relict gypsum neoformations are distinguished by their high strontium content. In a number of cases the amount of this element is so high that strontium sulfate (celestite) is formed. The neogenetic celestite is paragenetically associated with columnar gypsum. Neogenetic celestite has not been detected among the modern gypsum neoformations.

The mineral is of light brown color, with crystals of a finely-prismatic habit, not exceeding 4 mm along the first crystallographic axis. The crystals are formed primarily by faces of the form {001}. The form {001} occurs rarely, in the shape of narrow, smooth faces. The crystal head is formed by rounded uneven faces {hKl}. Very rarely, small mat faces {100} are to be seen. Intergrowths along the faces {011} and {011}, forming platey aggregates.

Table 6

Rational analysis of relict gypsum neoformations, percentage weight

Component	Columnar gypsum, Chu-Ily mountains	Gypsum crust (top), Syria
H_2O 105°	19,46	20,05
CO_2	Not det'd.	1,95
	10% Na_2CO_3 extract	
SiO_2	Not det'd.	0,17
Al_2O_3	"	0,10
Fe_2O_3	"	0,49
	10% HCl extract	
SiO_2	0, 56	0,11
TiO_2	Traces	Not det'd.
Al_2O_3	"	0,10
Fe_2O_3	0, 9	0,13
MnO	Not det'd.	Traces
CaO	31, 75	32,46
MgO	Not det'd.	0,17
BaO	"	Not det'd.
K_2O	Not det'd.	Traces
Na_2O	"	1,16
SO_3	45, 09	41,62
	10% HCl extract	
SiO_2	0, 12	0,45
Insoluble residue	1, 42	1,06
Total	98, 49	99,74
Total free SiO_2	0, 68	0,73

Note: Comma represents decimal point.

Radial-fibrous aggregates occur. Microconcretions 0. 2 mm in diameter are found on occasion, their central part consisting of a turbid amorphous mass and the periphery of cryptocrystalline celestite. Supergene celestite from the desert belt Quaternary deposits is morphologically and crystallographically distinct from the celestite widely distributed in the Central Asian Mesocainozoic deposits (24).

The refractive indixes, determined by the immersion method, are Ng' = 1. 630 ± 0. 003; Np' = 1. 621 ± 0. 003. In well-formed crystals dispersion of the refractive indixes, of the order of 0. 006, can be noted. Under the microscope the crystals are often seen to contain a large amount of pelitic substance from the Quaternary deposits. The number of these particles can be determined from the intensity of the brown tint in the mineral. Crystals without pelitic particles are colorless.

The composition and content of admixture elements in neogenetic celestite from the Quaternary deposits differs from that in celestites from marine sedimentary deposits.

Among the admixture elements in the celestite studied it is possible to distinguish a group of chemical elements whose presence is due primarily to the content of pelitic particles in the parent rock (Si, Al, Fe, Mg, Ca, Na, Ti and Mn). In crystals more or less contaminated with pelitic particles, Ga, Ni, Gr, Zr and V, not detected in the purest crystals, are periodically found. Barium (in amounts varying from 0. 1% to 1. 0%) and copper (in hundredths of a percent) are invariably found even in completely pure crystals. These elements and, to some extent calcium, magnesium and manganese, apparently form part of the celestite crystal lattice.

Summary

The foregoing material shows that the Quaternary desert belt deposits contain numerous neoformations, manifestations of supergene transformation of these deposits.

The complicated history of the desert landscape has brought into existence two groups of neoformations, substantially different from each other. One consists of relicts of ancient stages of regional hydromorphic supergenesis, the other is the result of supergenesis under conditions of acute moisture deficiency. The modern neoformations belong to the second group.

AGRONOMY

The two groups differ in regard to the conditions of their occurrence and their outward appearance. They are similar in a number of mineralogical, micro-morphological and geochemical characters.

The neoformations studied are characteristic exclusively of supergenesis under the landscape-geochemical conditions of subtropical deserts and are not typical of the supergene effects occurring under other conditions. The greater part of these neoformations are resistant to subsequent supergene processes and are not destroyed when landscapes change. The neoformations studied must therefore be regarded as typomorphic manifestations of desert supergene effects.

The foregoing data should be taken into account in regional examination of supergene neoformations for purposes of paleographical reconstructions, landscape — geochemistry and certain other types of research.

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CAPILLARY MOVEMENT AND ACCUMULATION OF MOISTURE IN STRATIFIED SOILS

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Capillary Moisture Capacity

The laws governing capillary movement and accumulation of water in stratified soils are still inadequately known, despite their exceptionally great importance for productive and theoretical purposes. The existing information on moisture capacity in stratified soils (3, 8) relates to moisture suspended by capillary and describes certain laws connected with the critical moisture capacity of such soils. Rozov (6) and Rode (7) commented on A. F. Lebedev's data.

This paper is based on the results of a laboratory experiment in glass tubes 2.7 cm in diameter and 100 cm long. The material used for stratified soils in the tubes consisted of: 1) clay from lacustrine deposits in the lower reaches of the Amu-Dar'ya (taken from a depth of 10-30 cm); 2) sand from deposits along the streams in the lower reaches of the Amu-Dar'ya from the 2 m layer; 3) fine-textured clay loam (loess from a terrace of the Tashkent cycle [after Yu. A. Skvortsov] from a depth of 4 m).

This material was first ground in a mortar and sieved through a sieve with 1 mm diameter opening. The fractions smaller than 1 mm in diameter were packed into the tube by means of a wooden tamper, by 2.5 cm sections, packed to 1.4 bulk density. This was achieved by packing a specified weight sample into a given volume.

The analyzed characteristics of the clay, fine clay loam and sand are shown in Tables 1, 2, 3 and 4.

Figure 1 is a schematic diagram of the experiment, designed to permit study of the capillary moisture capacity of four soil categories[1]: 1) of uniform texture; 2) stratified soils (texture becoming coarser from the bottom up); 3) stratified soils (texture becoming finer from the bottom up); 4) stratified soils with mixed distribution of layers of different textures.

The technique for performing the experiment was as follows. Samples prepared, as indicated in the glass tubes, were bound with gauze and a single layer of filter paper at the bottom edge and placed in half-liter jars containing distilled water for capillary saturation. The water-level in the jars was kept constant at 1 cm above the bottom of the tubes throughout the experiment. Once the moisture had risen by capillarity to the column height a further supply of water was fed from below for 46 days and moisture losses from the surface through evaporation were observed; one tube was then covered with a porcelain lid for 7 to 10 days, for each treatment, to eliminate evaporation and restore the capillary moisture capacity, while another was left open. After this the tubes were taken from the water, laid horizontally, and cut into 5 cm sections. Each of these soil sections were placed in a glass beaker and put into a thermostat kept at a constant temperature of 105°C to dry, so that the moisture could be determined.

The figures obtained are discussed below.

Capillary Moisture Capacity of Soils of Uniform Texture

In these soils the capillary moisture capacity was studied in clay, fine clay loam (loess) and sand columns of varying thickness (100 cm, 75 cm, 50 cm, 25 cm). The results of the observations are shown in Fig. 2. They confirm the known propositions that in uniform grounds:

1) capillary moisture capacity depends on the particle size composition of the soils and their height above the free water surface (1, 6, 7);

2) the capillary fringe in sandy grounds falls into two zones as regards the character of the wetting: a lower zone, with a high uniform moisture and an upper zone with decreasing moisture (1, 4, 6, 7).

On the basis of these data, it is impossible to agree with Rozov (6, p. 58) that in uniformly constituted soils of different particle size composition this type of moisture distribution in the capillary fringe does not alter as conditions

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[1] The capillary moisture capacity was determined in the same tubes as those used for studying the rate and height of capillary rise. The results were published in Pochvovedeniye, 1959, No. 3.

Table 1

Particle size analysis of ground soils (Pipette method, sodium hexametaphosphate treatment), %[a]

Sample	Particle diameter, mm							
	>0,25	0,25—0,10	0,10—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	< 0,01 (physical clay)
Sand	1,36	0,59	5,47	6,65	22,66	38,45	24,55	85,66
Fine clay loam (loess)	0,37	0,29	11,29	40,65	26,00	10,75	10,65	47,40
Sand	0,47	6,46	57,67	32,25	1,45	0,25	1,45	3,15

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[a] Analyst V. P. Maskin.

Note: Comma represents decimal point.

Table 2

Micro-aggregate composition, %[a] (N. A. Kachinskiy method)

Sample	Micro-aggregate diameter, mm						
	>0,25	0,25—0,10	0,10—0,05	0,05—0,01	0,01—0,005	,005—0,00	<0.001
Sand	0,70	0,60	3,90	28,00	24,60	33,80	8,40
Fine clay loam (loess)	0,30	0,30	8,70	63,90	14,20	9,20	3,40
Sand	0,40	1,80	73,50	23,30	0,20	0,20	0,60

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[a] Analyst L. Ye. Shapovalova.

Table 3

Humus content and composition of water extract, % of air-dry soil[a]

Sample	Humus	Density composition	Alkalinity		Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	$Na^+ + K^+$
			$CO_3^=$	HCO_3^-					
Clay	1,22	0,412	None	0,026	0,088	0,138	0,034	0,017	0,061
Fine clay loam (loess)	0,17	0,104	0,014	0,045	0,007	0,025	0,014	0,004	0,009
Sand	0,19	0,314	None	0,016	0,081	0,093	0,093	0,009	0,060

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[a] Analyst N. F. Alekseyanko.

Note: Comma represents decimal point.

vary and that modifications are expressed only in the absolute moisture values and the vertical extent of the zones. Our doubts as to the validity of this contention are due to our failure to find any zones of high constant moisture in the clay soils. On the contrary, the amount of moisture in these soils tended to decrease, starting with the very bottom of the column.

A decrease in moisture content from the bottom upward was observed in the clay loam (loess) columns, also, although here there were practical difficilties in detecting this decrease within the limits of one meter, since the moisture-rise capacity of clay loam loesses is, as we know, much higher than that of clays, and the curve of moisture decrease with height is less steep in clays. This is evidently the explanation for the larger particle-size and micro-aggregate constitution of the loesses, the influence of friction on the height of capillary rise being less pronounced. It therefore looks as though the contention that the capillary fringe can be divided into two zones, one with

Table 4

Physical properties

Sample	Particle. density g/cm³	Bulk density g/cm³	Porosity, %	Max. hygroscopicity, %[a]
Clay	2,66	1,40	47,40	7,26
Fine clay loam	2,65	1,40	47,20	3,87
Sand	2,65	1,40	47,20	2,96

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[a] Determinations by M. U. Umarov

Note: Comma represents decimal point.

a constant and the other with a sharply decreasing moisture, has no universal significance.

On the basis of the experimental results it is also difficult to agree with assertions contradicting Lebedev's opinion (4), to the effect that the column height does not substantially affect the moisture, which is based, in particular, on Proskurnikov's experiments with sand (5).

On the contrary, our data indicate that the column height does influence the moisture, but only where there is free capacity in the soil for this to happen; in other words, where the percentage of moisture in the soils at a given height along with the trapped air, is below the porosity percentage. The smaller this capacity, the greater will be the influence of the column height on the change in capillary moisture capacity. For example, comparing the moisture capacity in clay columns of various sizes, at comparable heights, we found that the moisture in the top part of a 75 cm column was much greater than at the same height in a 100 cm column, while in the lower part it was somewhat less. In the top part of a 50 cm column the moisture was again much higher, but fell very slightly in the lower part of the column. Some decrease in the moisture was observed also in the 25 cm column as compared with the same layer in the 100 cm column, possibly because the column was inadequately protected from evaporation. In the 25 cm column, however, we observed some rise in moisture in the topmost layer. It is interesting that this rise was noted in all the fine clay loam (loess) columns in the experiment, yet it was not possible to detect any influence of their height on the change in moisture capacity. Nor was such influence noticed in the sand columns. A rise in moisture in the top horizons was observed in the 25 and 50 cm sand columns.

Inadequate protection from evaporation in the experiment made it impossible to discover the full effect of column height on the moisture

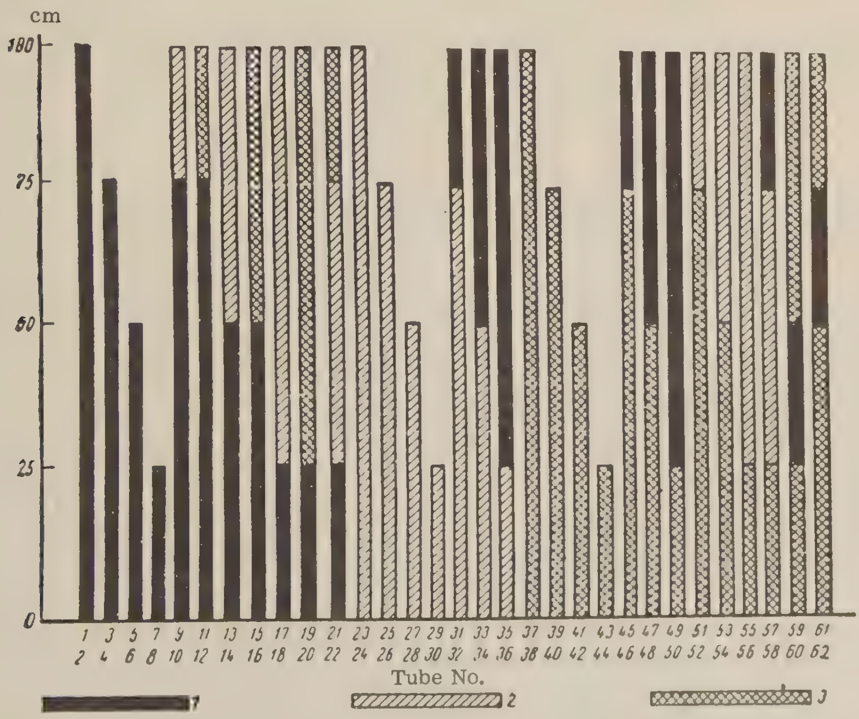

Fig. 1. - Scheme of experiment.

1 - clay; 2 - fine clay loam (loess); 3 - Sand; 4 - Tube No.

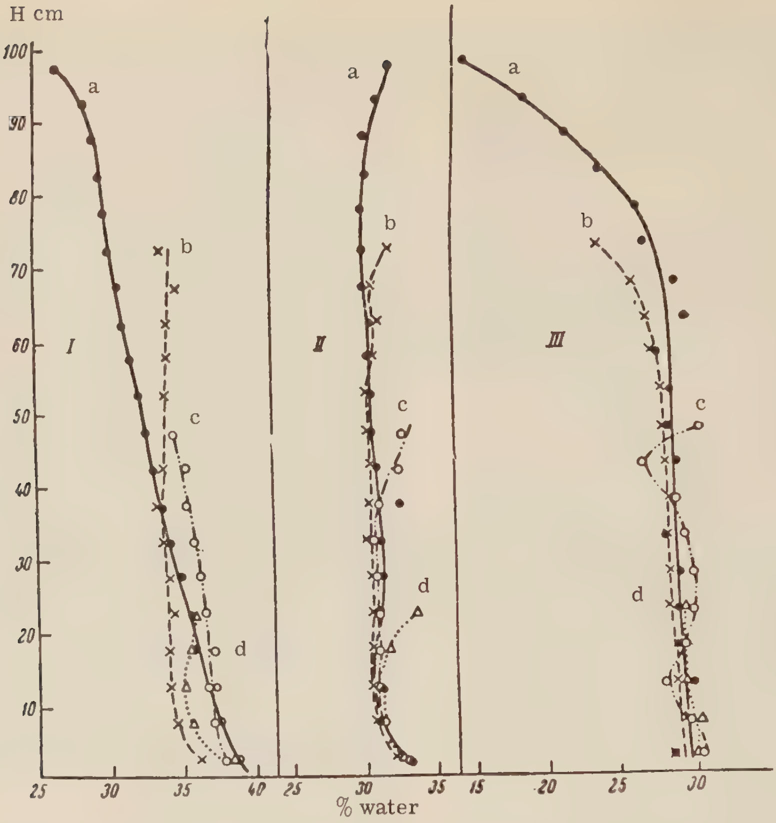

Fig. 2. - Variation in capillary moisture capacity of uniform soils, as a function of column height.

Columns: I - clay; II - fine clay loam (loess); III - sand column height: a - 100 cm, b - 75 cm, c - 50 cm, d - 25 cm.

capacity of the soil, but the figures obtained show that such influence does occur and that it can be accounted for by the following reasons.

Capillary movement and moisture accumulation in soils depends on the ratio between the integral values of forces (operating at a given force level) (menisci forces) and inhibiting (weight of water column and friction) capillary rise. Capillary movement continues until the former forces balance the latter. Once equilibrium between these forces sets in, capillary movement ceases and the moisture in the soil stays at the level of the peak height of capillary rise. It is then in a relatively static condition. All the processes of hydraulic equilibration of the system, occurring during capillary movement, have now ended. Equilibration of the system in this case has occurred without the column height being limited and therefore the water levels in capillaries of various diameter, apart from the narrowest diameter determining the height of capillary rise, are in the lowest position for the given system, since the damping of pressure created by the menisci forces has been effected by the weight of the growing column of water in the narrowest capillary when it is being fed with water from larger capillaries.

Let us assume that the height of the column is less than the height at which moisture can be raised by capillarity in a given material, and that the moisture in the top part of the soil is less than in the part directly adjoining the free water surface (that is, that there is free capacity in the top part of the soil column). In this case, the further capillary rise of moisture has been limited not by the properties of the soil but by the inadequate height of the column; the menisci forces, not offset by the weight of the water column and by friction, start to diminish owing to the increase in the size of the water columns successively in all the larger pores while the feeding of the small pores from the larger ones continues. This process is accompanied by an increase in moisture in the top part of the soil and sometimes by a relative decrease in the moisture amount in the bottom part of the soil (a result of the fact that the small pores are being fed from large ones).

Let us assume that the column height is equal to or less than that part of the capillary fringe where the moisture approaches the maximum value of capillary moisture capacity proper to the bottom layers. The column height cannot then have any appreciable influence on the capillary moisture capacity, since the soil is in a condition of almost complete capillary saturation; but the height limitation of the column causes the uncompensated menisci forces to diminish, owing to the increase in the size of the water columns in the water-free capillaries at the top end of the soil column and owing to the smoothing of the menisci forces in the smallest pores, which have filled with water. This creates a certain increase in the moisture in the topmost parts of the columns as, for example, in our experiment in all four columns of the fine clay loams, in the 25 cm clay column, and in the 50 and 25 cm sandy columns.

The foregoing propositions are important for understanding the processes determining capillary moisture capacity in stratified soils.

Capillary Moisture Capacity of Stratified Soils (Texture Becoming Coarser From the Bottom to the Top)

Six treatments of soil columns were used (Fig. 3). As was to be expected, the capillary moisture capacity did not decrease smoothly with height as it did in the uniformly textured soils. On the contrary, the moisture distribution along the soil profile had a step-like character. An abrupt change in the amount of moisture followed a variation in the particle size composition of the soils, and this determines the undoubted relationship between capillary moisture capacity and the particle size composition of the components. Here, however, the capillary moisture capacity of particular soil in the profile of the stratified soil diverges sharply from that of the same soil at corresponding heights in a uniformly textured soil. The degree of this divergence varies with different textures and thicknesses of the soil combinations. It follows that the capillary moisture capacity of the soils in a stratified system, just as throughout the stratified column, depends not only on the particle size composition of the soil combination but also on the ratio of their thicknesses and further on the height of the different soils above the free water surface. This, however, does not cancel out the definite pattern of capillary moisture distribution in the soil profile of this particular type.

First, capillary moisture capacity of the top layers prove lower, in all cases, than in the same soils at corresponding heights in soils of uniform texture. The difference is proportional to the difference in particle size composition of the component soils and to the width of the ratio between the thicknesses of the top and bottom layers. We attribute this effect to the considerable friction of the water as it passes through the bottom layer, which is finer-textured in these than in the uniform soils consisting of top layer soils. As a result, the capillary rise of moisture in the latter, at corresponding heights, is effected through smaller pores (9).

Secondly, a certain tendency for the capillary moisture capacity in the bottom layer soils to decrease, as compared with corresponding heights in the same soils of uniform texture, as the thicknesses of these layers increases. A marked deviation from this pattern is observable only in columns 11 and 12, where the thickness of the bottom layer evidently exceeds the maximum height of capillary rise of the sand (in the given combination) forming

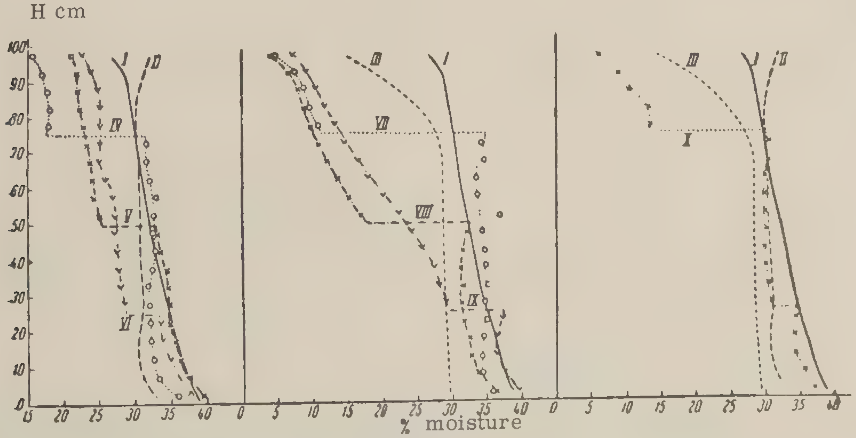

Fig. 3. - Capillary moisture capacity of stratified soils with texture becoming coarser from the bottom toward the top.

Soil texture: I - clay, 100 cm; II - fine clay loam, 100 cm; III - sand, 100 cm, IV - clay 0-75 cm; fine clay loam 75-100 cm, V - clay 0-50 cm; fine clay loam 50-100 cm; VI - clay 0-25 cm; fine clay loam 25-100 cm; VII - clay 0-75 cm; sand 75-100 cm, VIII - clay 0-50 cm; sand 50-100 cm, IX - clay 0-25 cm; sand 25-100 cm, X - clay 0-25 cm; fine clay loam 25-75 cm; sand 75-100 cm.

the top layer. In this case the capillary moisture capacity of the bottom layer even rises in its top part but falls slightly in the lower part.

The pattern of events underlying the establishment of capillary moisture capacity in the bottom layers can be explained on the basis of the following theoretical considerations:

1) let us assume that the thickness of the bottom layer is less than the maximum height of capillary rise of the water in the particular uniform soil, but that the height of this layer is greater than the maximum height of capillary rise in the soil of the top layer. The capillary rise will then be limited mainly by the interface. In such a case the menisci forces are still not counterbalanced by the water column and friction. As a result they diminish with increased water column in the more or less large capillaries of the bottom layer, in which the water has been kept at a lower level in the course of capillary rise (the result of hydraulic equilibration of the system through the feeding of small capillaries from larger ones). As a result, the water capacity in the bottom layers increases, but at heights where there is free capacity for such increase. This was the case in columns 11 and 12.

2) Let us now imagine that the thickness of the bottom layer does not exceed the height of capillary rise in the top-layer soil. The capillary rise, having reached the interface, will then continue in the upper layer. Let us assume that in this layer it reaches its maximum height, as for example in columns 15 and 16. This is a more complicated case of moisture accumulation. First, in the course of rising by capillarity from the bottom to the top layer, the moisture strikes a system of larger pores, and this reduces the integral value of the forces causing capillary rise, and consequently somewhat reduces the levels of the water columns in the large capillaries of the bottom layer. Secondly, hydraulic equilibration of the entire system, owing to the feeding of small pores from larger ones, has an even greater effect in reducing the column levels in the large pores. All this also leads to some lowering in moisture capacity in the soils of the lower layers as compared with that of the same soils in the uniform texture we were considering previously.

The foregoing exposition shows that the particle size composition of the top layer affects the moisture capacity of the lower layer. The considerable reduction in moisture capacity in the bottom layers as their thickness increases was explained in the previous section. It is to be noted that the reduction in the moisture capacity of the rocks in the lower layer was observed only in a case where the factors indicated, determining this reduction, were capable of lowering the water levels in the large capillaries of these layers to a height less than their thickness.

3) Lastly, let us assume that the height of the bottom layers does not exceed that of capillary rise in the soil of the top layer, but that the height of the whole column is less than the maximum height of capillary rise in the soil of the top layer (in a given combination of soils). In this case, the limitation of the column height has an influence on the integral value of the forces causing capillary rise, and this also tells on the moisture capacity of the bottom layer.

All the foregoing patterns remain in force in both double and triple layered soils.

Capillary Moisture Capacity of Stratified Soils (Texture Becoming Finer From the Bottom Toward the Top)

Observations on capillary moisture capacity in this system were made on ten different soil treatments (Fig. 4).

This system of layers resembles the one discussed previously in that the capillary moisture capacity did not diminish smoothly with height, as in the uniformly soil textures. The moisture distribution along the profile had a stepped character.

Abrupt changes in the amounts of moisture followed change of texture in the layers and consequently the capillary moisture capacity of these soils was again unequivocally dependent on the texture of the materials making up the column. Here too the constitution of the soil — the combination of materials and the ratio of their thickness — had a considerable influence on the variation of moisture capacity in the soils as compared with the uniformly constituted soil. The distribution of moisture along the profile, however, followed a different pattern. Specifically, whereas in the previous category, where the fine-textured layers were at the bottom and the coarser-textured layers at the top, the moisture capacity of the top layers was less than that of the same materials at equivalent heights in uniform soil texture, the reverse was true here. These variations were not observed only in cases where the top layer was at a height at which the moisture in the soil approximated to the maximum capillary moisture even when the constitution of the soil was uniform, as for example, in columns 52, 54 and 56, where sand was combined with loess.

Consequently, the possible quantitative variations in capillary moisture capacity of particular soils in the profile of stratified soils is not so affected by their constitution that it exceeds the limits of the total capillary and molecular moisture capacity. The total capillary capacity expressed as a percentage, never reaches porosity, since some of the pores are always occupied by trapped air (7).

Within these limits, the degree of variation in capillary moisture capacity of the soils making up the top layers as compared with that of a uniformly constituted soil evidently depends mainly on two factors: first, on the fact that in these soils the bottom layers consist of coarser-textured soils, in which water friction is less (this increases the height of capillary rise in the top layers (9) and consequently increases their moisture capacity); secondly the height of the top layer above the free water surface.

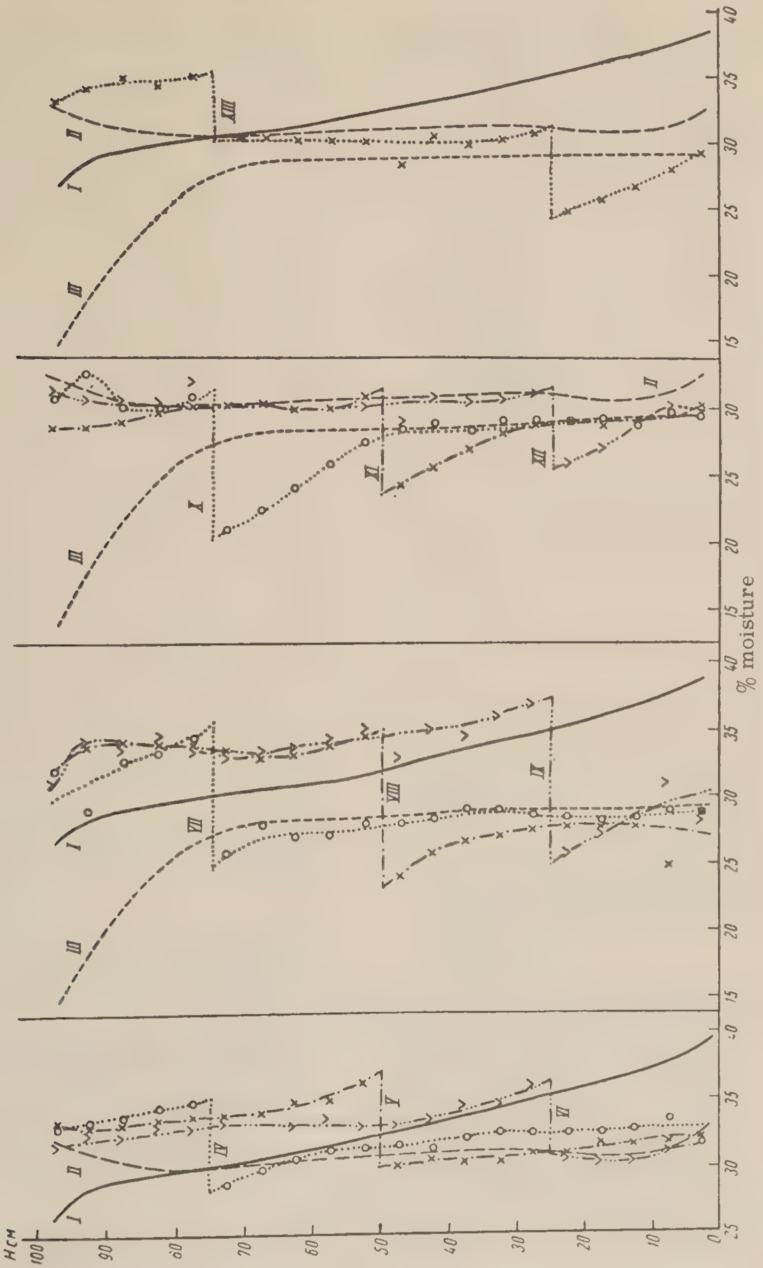

Fig. 4. - Capillary moisture capacity of stratified soils with texture becoming finer from the bottom toward the top).

Texture of soil: I - clay, 100 cm; II - fine clay loam, 100 cm; III - sand, 100 cm; IV - fine clay loam 0-75 cm; clay 75-100 cm; V - fine clay loam 0-50 cm; clay 50-100 cm; VI - fine clay loam 0-25 cm; clay 25-100 cm; VII - sand 0-75 cm; clay 75-100 cm; VIII - sand 0-50 cm; clay 50-100 cm; IX - sand 0-25 cm, clay 25-100 cm; X - sand 0-75 cm; fine clay loam 75-100 cm; XI - sand 0-50 cm; fine clay loam 50-100 cm; XII - sand 0-25 cm, fine clay loam 25-100 cm; XIII - sand 0-25 cm, fine clay loam 25-75 cm, clay 75-100 cm.

The first factor increases the moisture capacity of the top layers in proportion to the component layers; that is, in inverse proportions to the friction in the bottom layer. The second factor can reduce the effect of the first, since at a given height individual large pores of the top layer are no longer capable of supplying water from the smaller, lower-layer capillaries operating at these heights. The textural make-up of the columns causes a substantial variation in the moisture capacity also of the lower layers in these soils as compared with that of the corresponding uniform soils. This variation is characterized by some lowering of the moisture capacity in the top parts of the bottom layers, which is particularly sharp in the immediate vicinity of the interface. This effect is apparently connected with the hydraulic equilibration of the system, as a result of which the large pores of the bottom layer partly feed the smaller top-layer pores adjacent to them.

All these factors condition the capillary moisture capacity of triple-layered soils, too. The figures for column 58 provide evidence of this.

Capillary Moisture Capacity of Stratified Soils of Different Textures

Two soil treatments were used. The results of the investigations (Fig. 5) show that the characteristic patterns of the type II and III soils operate in regard to the accumulation of capillary moisture in these soils. As in the second category of soils, capillary moisture capacity in the top layer proves lower than at corresponding heights in uniform soils. This is due to the influence of water friction in the subjacent clay layer. The degree of this influence is not affected by the height at which a clay layer of given thickness may occur.

In the middle (clay) layers of these soils, over sand, the capillary moisture capacity is higher than in the same uniformly constituted soils, since water friction in sand is less than in clay. The observed rise in moisture in the clay layer on top, at the interface, is evidently due to the fact that the height of the whole column is limited; as a result, the hydraulic equilibration of the system leads to a smoothing-out of the menisci forces at the interface in those capillaries of the clay layer from which the water cannot pass into the top, sandy layer because the pores are of different sizes.

In the bottom sandy layers in these soils the capillary moisture capacity is found to decrease by comparison with the same uniform soil. This decrease occurs mainly in the top parts of the bottom layers and is due to hydraulic equilibration of the whole system effected through the partial feeding of the small capillaries from the bigger ones.

The capillary moisture capacity of soils in stratified soils thus has a conditional character. It depends on the constitution of the soil — the texture of the component materials, their thickness, and the height at which they occur in the system, the height of the columns and the factor of hydraulic equilibration of the system through the feeding of small pores from larger ones.

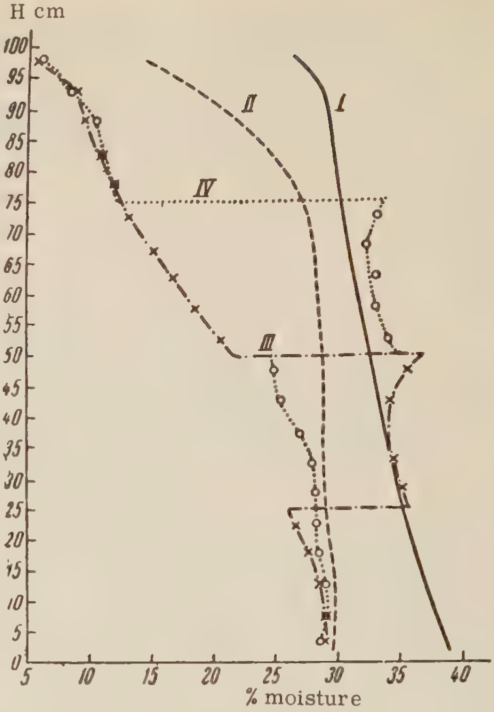

Fig. 5. - Capillary moisture capacity of stratified soils consisting of layers of various texture.

Texture of soil: I - clay, 100 cm; II - sand, 100 cm; III - sand 0-25 cm; clay 25-50 cm; sand 50-100 cm; IV - sand 0-50 cm; clay 50-75 cm; sand 75-100 cm.

All our conclusions are based on data obtained from observations on columns protected from evaporation, which substantially distorts the phenomena of capillary rise and moisture accumulation.

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STABILIZATION OF SOILS BY ACRYLIC ACID DERIVATIVES

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Various makes of kriliums have been in use abroad for forming artificial soil structure lately. The commonest is Merloam, produced by the American firm, Monsanto Chemical Company in St. Louis, Mo. In the USSR successful experiments have been made by the staff of the Agrophysics Institute in subjecting various soils to form structures artificially. The polymers used were acrylic acid derivatives of Soviet manufacture (polyacrylamid and copolymer VIII).

In conjunction with Eng. A. I. Zaikin, I investigated the properties of these polymers with the aim of using them to stabilize soils for various land improvement purposes. Comparative laboratory experiments yielded the following results.

Polyacrylamid is soluble in water but partially loses solubility on prolonged contact with the soil. A strong coagulator appreciably increases the viscosity of the solutions; small lumps of soil and aggregates put into a 0.1 (or more % polyacrylamid solution do not slake and are not dispersed. The solutions penetrate the soil pores poorly: polyacrylamid impregnating soil which is not in a friable state does not usually penetrate deeper than 3 mm. A film 3 mm thick from soil stabilized with polyacrylamid does not become soaked in water for 5 to 10 days or more. When large volumes of water (150-200 mm) are percolated through a film of stabilized soil the polyacrylamid is leached and water stability is lost.

Copolymer VIII is soluble in weak ammonia solutions (0.5%-1.0%), practically insoluble in water in a neutral or acid medium and is not a coagulator (an ammonia solution of Copolymer VIII has a weak dispersion effect on soils. In comparison with polyacrylamid the Copolymer VIII solutions were adsorbed several times more quickly and penetrated to greater depth both in friable and in non-friable soils. The copolymer fixed well in the soil, making it water-stable. The stabilized soil films and samples impregnated with the copolymer did not become water-soaked for thirty days. The copolymer was not completely leached when 4000 mm of water were percolated through the stabilized layer and the stabilized soils retained their water stability after the experiment.

The Monsanto Merloam krilium is readily soluble in water and is a poor coagulator. Compared with polyacrylamid it gives a less viscous solutions, which penetrate deeper into the soil pores, but it is leached from the soil by percolation. Soil films 3 mm thick stabilized with this preparation become water-soaked in two or three days.

The addition of any of these polymers to soils makes little difference to their cohesive and capillary properties (Table 1).

In laboratory tests on the soaking of cubic-shaped samples and half life-size models of a krotovina,[1] two methods of stabilizing the soils with acrylic acid derivative polymers were studied: impregnation and mixing. The minimum and optimum amounts of stabilizer addition were established (Table 2). It was found that minute additions of 0.0001% of these polymers increased the amount of water-stable aggregates in the soil grounds. The water stability of the aggregates increased in proportion to the amount of stabilizer and the aggregates became increasingly consolidated, until the samples ceased to break down into aggregates. It is important to achieve this condition for many melioration problems requiring that the soils should not slake or the stabilizer be leached out. For sandy loams and clay loams the quantitative specifications for the addition of stabilizers which would appreciably retard the slaking of the samples (slowing it down by a factor of 50-100) are given in Table 2 ("minimum" column). Further additions of stabilizer continue substantially to increase the water stability and prolong the time taken for the samples to become soaked in water. Above a certain amount, however, the effectiveness of further additions starts to diminish and finally becomes negligible for practical purposes (Table 2). In a number of cases very large additions of stabilizer leads to gradual reduction of the water stability.

In impregnation stabilizing, the choice of concentration depends not only on the characteristics of the stabilizer but also on the porosity

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[1] V. I. Bobchenko. Laboratory and laboratory-field methods of determining the stability of krotovinas in irrigation. Dokl. VASKhNIL, 1958, 11.

Table 1

Effect of polymer additions on the resistance of soil to crushing and on its capillary properties

Test number	Treatment number	Experimental treatment	Amount of polymer, % dry ground weight	Resistance of air-dry sample to crushing, kg/cm²	Average rate of capillary rise, mm/min	
					During first 10 minutes	At height of 60 mm
1	1	Control, without additions	None	5,15	22	12
	2	Polyacrylamid added	0,060	4,62	26	15
	3	Same	0,125	4,98	33	23
	4	"	0,250	10,68	36	26
	5	"	0,500	10,17	Not det'd.	
2	1	Control, without additions	None	5,15	22	12
	2	Copolymer VIII added	0,060	5,00	19	15
	3	Same	0,125	6,47	22	15
	4	"	0,250	7,25	17	7
	5	"	0,500	11,17	Not det'd.	
3	1	Control, without additions	None	2,38	22	12
	2	Merloam krilium added	0,060	0,75	29	19
	3	Same	0,125	0,93	29	18
	4	"	0,250	0,99	37	27
	5	"	0,500	1,17	Not det'd.	

Note: Comma represents decimal point.

Table 2

Polymer amounts required to ensure non-soaking of samples as a result of mixing and water stability of impregnated layer of soils, % by weight

Polymer	Amount of soil on mixing		Amount insolution of impregnation of soil	
	Minimum	Optimum	Minimum	Optimum
Polyacrylamid	0,03	0,10--0,20	0,08	0,25
Copolymer VIII	0,04	0,20	0,10	Not det'd.
Merloam Krilium	0,06	0,30	0,14	0,40

Note: Comma represents decimal point.

of the soil and its moisture content and other factors. The main condition for successful stabilizing is that sufficient amounts of stabilizer should penetrate the soil pores. In moist soils this process is complicated by the low penetrability of the pores and the dilution processes as the solution penetrates deeper. In the case of polyacrylamid and Merloam krilium the "minimum" concentration, which is for practical purposes low, is connected with the necessity of giving the solution coagulating properties. Without such properties the aggregates will slake and penetration by solution of these stabilizers, which have high viscosity, will be greatly retarded. If the concentration is increased too far above the "optimum", the solutions will become too viscous, limiting their penetration in the pore.

In the case of copolymer VIII, the "minimum" concentration is determined by the addition of a cementing substance into the soil pores in an amount sufficient into the soil pores in an amount sufficient to form a waterstable crust. Table 2 shows the concentrations of solution required for friable soils under conditions of moisture ranging from air-dry to wilting percentage.

The water stability of stabilized soils increases with time, particularly during the first few days after stabilizing. Determination of the resistance of soils to water erosion, by

V. B. Gussak's laboratory method (tray model 8D), showed that when 0. 04% of polyacrylamid is mixed with the soil the erosion time of a standard sample increases by a factor of 8000 or more. Impregnation of air-dry samples with a 0. 25% polyacrylamid solution in an amount of 0. 04% by weight increased the erosion time by a factor of 10, 000 or more.

Field tests at the Kursk Regional Experimental Improvement Station showed that steep slopes and scarps could be successfully stabilized by polyacrylamid. Plots on a 0. 08 gradient stabilized by mixing the top 8-10 cm layer with 0. 1% by weight of polyacrylamid were erosion-tested for four hours by passing a 10 liter per second flow through them at mean speeds of 1. 1 to 2. 0 meters per second. The average thickness of the eroded layer in the stabilized plots did not exceed 1 mm, against 35 mm in the control (unstabilized) plots.

To increase the effectiveness of impregnation stabilizing a mixture of equal volumes of polyacrylamid and Copolymer VIII in concentrations of 0. 10%-0. 13% of each stabilizer, kept in 0. 5% ammonia solution, was used in the experiments. The mixed stabilizer combined the good points of both components. Polyacrylamid in 0. 10%-0. 13% concentration prevented the soil lumps from slaking and the pores from silting up, owing to its strong coagulating action. Surface soils, the scarps of canals and embankments, mole-drains and irrigation ditch can be treated with it for a long time without slaking or silting. A solution of copolymer VIII penetrates two to three times as deep through non-slaked pores, as compared with its penetration in pure form (without polyacrylamid).

Arch models of life-size krotovinas made of sandy podzolized loam and impregnated with a mixture of copolymer VIII and polyacrylamid solutions survived ten tests in water, lasting 30 days altogether (720 hours) without breaking down. Some of these sample models were frozen to -10°C in the intervals between tests. The control samples broke down on the first test after about one hour.

In sod-podzolic sandy loams, segments of artificial krotovinas stabilized by impregnation for 30 minutes with a mixture of copolymer VIII and polyacrylamid, survived five subsoil irrigations at the rate of 5000 m³/ha (500 liters of water per linear meter of krotovina). The unstabilized control segments did not survive more than one subsoil irrigation (100 liters per linear meter).

Sufficiently high water stability was retained by artificial drains stabilized by impregnation with a mixture of polyacrylamid and copolymer VIII solutions (Fig. 1), where the root system of agricultural crops also penetrated through the walls of the drains. In pot experiments, good development of the root system of barley was observed in soil stabilized with a mixture of barley was observed in soil stabilized with a mixture of 0. 1% of polyacrylamid and subsequent compaction under loads of 1 kg/cm².

In practice the stabilizing of artificial krotovinas for sub-soil irrigation by this method can be combined with the first irrigation, by effecting the mixture of solutions at a low irrigation rate of the order of 200-300 m³/ha. Here it is essential to use the technique of force subsoil-irrigation. With this method, of course, it is impossible to avoid using excessive amounts of stabilizer. In our experiments, for example, the actual amount of polyacrylamid and Copolymer VIII per linear meter of drain was 16 g of each stabilizer to a volume of 23 liter of solutions containing 120 g of ammonia, whereas according to the laboratory experiment data, 3 g of these polymers were sufficient for one linear meter of drain, in 2-4 liters of solution containing 10-40 g of ammonia.

In the pot experiment with barley and also in the observations on stabilized plots in the field,

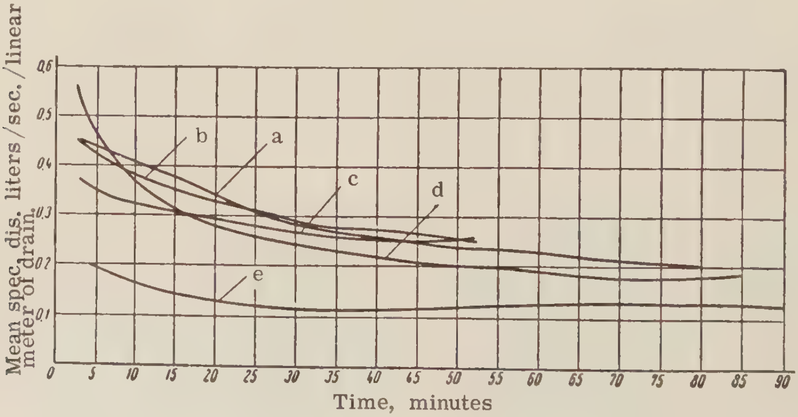

Fig. 1. - Discharge of absorbed water in subsoil irrigation through artificially stabilized drains 55 mm in diameter at a constant hydrostatic head of 30 cm.
Irrigation: a - first, b - second, c - third, d - fourth, e - fifth.

grasses and grain crops survived well in stabilized soils, even with additions of 0.1% - 0.3% by weight of polyacrylamid, a result which agrees well with the conclusions of Soviet and foreign investigators on the use of kriliums to improve the physical properties of soil.

Polyacrylamid and copolymer VIII are at present being produced in the USSR. In 1958 1959 polyacrylamid cost 1 ruble 60 kopeks per kg and copolymer VIII 3 rubles 90 kopeks per kg. It is planned to bring these prices down greatly in the next few years (22 kopeks for 1 kg of polyacrylamid, 66 kopeks for 1 kg of copolymer VIII.)[2]

Research results indicate good prospects for the use of acrylic acid derivatives for stabilizing soils for meliorative purposes, particularly in controlling erosion. Possibilities are opening up for stabilizing soils in places where rapid streams of water are concentrated; troughs and hollows, simplified temporary chutes, canals with steep gradients, the extremities of scarps in estuaries, where currents concentrate, points where large flood streams emerge into fields, steep slopes, highly permeable constructions of granulated stabilized soil for moisture accumulation, drainage, subsoil irrigation and so forth. Preliminary stabilization of steep slopes and scarps with polymers makes it possible to ensure an effective ground cover.

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[2] One ruble equals $0.25 according to Webster's New Collegiate Dictionary. 1960.

QUICK METHODS OF DETERMINING THE HUMUS COMPOSITION OF MINERAL SOILS

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In work on the genetic aspects of soil science it has become a fairly common practice lately to supplement the study of the soil's chemical and physical properties, mineralogical composition and micro-flora by determining the group and fraction constitution of the soil humus. Tyurin (5, 6, 7) has contributed a great deal in developing methods for this purpose and has suggested a number of procedures based on successively isolating different groups of organic substances from the soil: a) resins, fats and other compounds which can be extracted with an alcohol-benzol mixture and b) humic substances proper, which can be isolated by a 0.1 N solution of NaOH and subsequently divided into the humic and fulvic acid groups.

Considering the fact that the humic matter in soil is bound to the mineral part of the soil in different ways, Tyurin introduced fractional extraction of the humic and fulvic acids into the system of analysis, using the following procedures: a) humic substances, free or bonded to non-silicate forms of sesquioxides, are separated from non-decalcified soil by a 0.1 N NaOH solution; b) humic and fulvic acids bonded with calcium are separated by the same solution after the soil has been decalcified; c) humic and fulvic acids bonded with silicate forms of sesquioxides are extracted by treating the soil alternately with 0.1 N H_2SO_4 and 0.1 N NaOH.

Tyurin recommends a number of supplementary procedures such as determining the organic matter in the acid solution produced when the soil is decalcified; separating the humic and fulvic acids by a 0.1 N NaOH solution after hot hydrolysis of the soil with 1 N H_2SO_4, and other methods.

Using these procedures Tyurin established the pattern governing humus formation in different groups and subgroups of soils in the USSR (6), which have now been confirmed by many investigators.

The division of humic matter into groups and fractions must be to some extent provisional, since the humic and fulvic acids are closely interconnected by transitional forms. The characters typical of a particular group of humic substances can alter, having a tendency towards hydrolytic decomposition or, under certain circumstances, towards condensation. On reprecipitation as a result of hydrolysis, for example, humic acids partly dissolve in the acid, thereby acquiring properties peculiar to fulvic acids. The evaporation of acid solutions containing fulvic acids results in the precipitation of a gel, owing to condensation of the fulvic acids, with the result that they coagulate in an acid medium, like humic acids.

To obtain useful results in determining the composition of humus, therefore, it is very important to see that the analysis is performed under uniform conditions. This particularly applies to the temperature and reaction of the medium at which the precipitation of humic acids from alkaline extract is produced. The alkaline extract is acidified to a pH of about 3, the precipitation temperature should be about 80°C and heating should continue for 30 to 40 minutes.

Experimental work has revealed a number of technical shortcomings in this method of determining humus composition: the method involves prolonged preparatory operations (decalcification, for example), numerous treatments with acid and alkaline solutions, which to some extent modify the organic part of the soil, and very complicated processing of the analysis figures. Moreover, some groups of substances prove uncharacteristic. Ponomareva (4), on the basis of her investigations of mineral soil humus, notes the possibility of excluding from the analysis the group of substances extractable with an alcohol-benzol mixture. This group is quantitatively small and uncharacteristic and its exclusion does not substantially effect the subsequent course of the analysis.

The purpose of this work was to find out whether the Tyurin system could be shortened and devise quicker analytical procedures. We gave our interim views at the Conference on Methods of Studying Soil Humus held at the V. V. Dokuchayev Soil Institute on June 3, 1960.[1] The results of our methodological research on this question are set out below.

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[1] See Soviet Soil Science (Pochvovedeniye) 1960, No. 11 English page 1149.

1. The Possibility of Shortening the Tyurin System for Analyzing Humus Composition

We shall first consider the group of substances extractable with an alcohol-benzol mixture. The composition of this group is exceedingly varied: apart from fats, resins, waxes and various kinds of pigments, humic substances proper can also be extracted with such a mixture (for example, hymatomelanic acids). The absence of pattern in the variation of different soil groups as regards this group of substances is due to the small amount and great variety of them present in the soil. In itself, the group is of little interest for purposes of discovering the characteristic peculiarities of the humus in mineral soils, but the question is whether or not the results of the subsequent analysis are affected by omitting alcohol-benzol extraction. The answer is given in Table 1, which shows the results of determining humus composition first with and secondly without such extraction.

The data in table 1 show that in no case did the omission of this treatment make any important difference to the amount of the principal groups of humic substances extracted in the course of the analysis (humic acids, fulvic acids and residue).

The question arises: if treatment with an alcohol-benzol mixture is omitted, into which group do the substances which would be extracted by such a mixture fall in the subsequent course of analysis? The values in columns 2 and 3 of Table 1 indicate that they pass mainly into acid solution (on decalcification of the soil). This is particularly evident in the analysis of podzolic soils, where the amount of extractable substances is fairly large and therefore the content in substances extracted on decalcification is substantially increased when extraction is omitted.

On the other hand, although alcohol-benzol treatment can be omitted in determining the humuc composition of mineral soils, it certainly cannot be omitted in analyzing forest floor, grass and tree litter fall, peat and other material rich in plant residues.

We then examined the possibility of omitting analysis of fraction II of the humic substances extracted when the soil is treated alternately by 0. 1 N H_2SO_4 and 0. 1 N NaOH solutions. The consideration that led Tyruin to introduce determination of this group of humic substances into his system of analysis was that in soil treated with 0. 1 N H_2SO_4 solution the bonds between the silicate forms of iron and aluminum, on the one hand and humic substances on the other are destroyed, with the result that the latter can be extracted with 0. 1 N NaOH. As can be seen from Table 2, humic and fulvic acid carbon together makes up a fairly considerable proportion of the fraction II in some soils, of the order of 10%-12% of the total carbon content in the soil. Nevertheless, we have not succeeded in discovering any pattern at all in the content of this fraction in different soil groups.

The values in Table 2 show that the ratio of humic acid C to fulvic acid, C as calculated solely from fraction I, does follow a pattern

Table 1

Comparative data on soil humus composition with and without preliminary alcohol-benzol extraction (percentage of total organic C)[a] Analyst N. A. Pankova

Soil, depth, cm	% weight C	C substances extractable		Humic acid C		Fulvic acid C		Residual C	Humic acid C[c] / Fulvic acid C
		By alcohol-benzol	On decalcification	I[b]	II[b]	I	II		
Thick chernozem, plowed fulvic acidC 0—20	4,23	1,9 —	9,2 9,0	33,3 35,2	2,6 2,9	21,3 20,6	1,9 1,7	28,1 26,5	1,55 1,71
Strongly podzolic, under forest 0—7	0,56	10,7 —	14,3 26,8	8,9 7,1	1,8 1,8	21,1 21,4	1,8 3,6	37,5 39,3	0,46 0,36
Strongly podzolic, plowed 0—20	1,34	4,5 —	7,9 14,9	15,7 15,7	3,0 3,0	21,7 20,9	2.2 2,2	31,3 34,3	0,78 0,80

[a] Top figures with, bottom figures without preliminary alcohol-benzol extraction.

[b] In Tables 1 and 2: I -- humic and fulvic acid fractions extractable from soil by an 0.1 N NaOH solution after decalcification; II -- humic and fulvic acid fractions extractable by alternate treatment with 0. 1 N H_2SO_4 and 0. 1 N NaOH solution.

[c] In column Humic acid C/Fulvic acid C the designated ratio values between humic acid C and fulvic acid C by sum of fractions I and II.

Note: Comma represents decimal point.

characteristic of each soil group. From this point of view it seems to us perfectly permissible to omit fraction II from the analysis, but the ratio will obviously increase in the residue of humic matter (see the last two columns of Table 2).

Omitting alcohol-benzol extraction and fraction II makes analysis of the composition of mineral soil humus shorter, but the laborious process of decalcifying the soil, as well as the necessity for repeated treatment with 0. 1 N NaOH solution remains.

We attempted to work out a quicker and easily performed laboratory method, using a solution of sodium pyrophosphate for extracting the humic substances.

2. A Rapid Method for Determining the Humus Composition of Mineral Soils, using Sodium Pyrophosphate for Extracting the Humic Substances

The use of sodium pyrophosphate (0. 1 M solution with neutral reaction), like the use of certain neutral organic acid salts such as oxalic, tartaric, citric and other sodium salts, for separating humic substances from soils is based on the capacity of solutions of these salts to form insoluble residues or soluble complexes with calcium, iron, aluminum and other polyvalent cations with which humic substances in the soil are bonded.

A number of investigators have performed detailed methodological work on this question (1, 8, 9, 10, 11, 12) and have established that the extraction of humic substances with $Na_4P_2O_7$ solution takes several hours; repeated treatment with this solution does not greatly affect the yield of humic matter as it does with NaOH solution, even in the case of highly humic soils. The extraction temperature and the soil-solvent ratio is also of less importance if $Na_4P_2O_7$ is used.

Sodium pyrophosphate has been used in recent years for extracting humic substances from various soils and peats (see works by authors cited previously, and also 2, 13, 14, 18 and others). Drozdova (2) found that a single treatment of peats with 0. 1 M sodium pyrophosphate solution extracted as much humic acid as repeated treatment with 0. 1 N NaOH solution. Aleksandrova (1) established that a single treatment of a chernozem, podzolic, red earth and sierozem soil (without preliminary decalcification) extracted 60%-70% of the humic matter which could be separated by the Tyurin method.

Aleksandrova suggests that the mechanism of $Na_4P_2O_7$ action amounts to an irreversible exchange reaction among the cations, resulting in the formation of soluble humic, alumino- and ferro-humic salts. We shall return later to the reaction systems given by this author.

The reaction of the $Na_4P_2O_7$ solution is of great importance: the higher the pH of the solution, the greater the yield of humic matter (9, 10, 11, 16). Choudri and Stevenson (10) established that the maximum amount of organic matter is extracted when the soil is first treated with $Na_4P_2O_7$ solution and then with NaOH, particularly if this procedure is accompanied by treating the soil with an HCl· HF

Table 2

Comparative data on humus composition of soils as determined by the Tyurin method (percent of total organic C in soil)

Soil depth, cm	% weight C	Humic acid C		Fulvic acid C		Humic acid C / Fulvic acid C		Residue on separation from soil	
		I	II	I	II	single treat I+II	4 treatmts. I	Single treat. I+II	4 treatments I
Strongly podzolic, under forest 0—7	0,56	8,9	1,8	21,4	1,8	0,46	0,42	37,5	41,1
Sod-podzolic, under forest 4—7	4,03	17,4	5,0	24,3	4,0	0,79	0,71	34,7	43,7
Fulvic acid C 3—10	6,11	20,8	7,4	21,3	4,1	1,11	0,98	32,1	43,6
Meadow chernozem, steppe 0—7	7,35	30,3	6,0	19,6	2,8	1,61	1,55	31,2	40,0
Ordinary chernozem, plowed 0—20	4,79	31,3	9,2	16,7	2,9	2,06	1,87	33,5	45,6
Red earths forest 5—10	4,09	15,2	4,9	28,4	2,7	0,65	0,54	32,5	40,1

Note: Comma represents decimal point.

mixture, which destroys the bond between the humic substances and the silicates.

We used sodium pyrophosphate solutions of various pH to extract humic substances from soils. The 0.1 M $Na_4P_2O_7 \cdot 10\ H_2O$ solution had a pH of 9.7; by adding a few drops of concentrated H_2SO_4 we obtained sodium pyrophosphate solutions of pH 8.3 and 7.4. In addition, we tested a mixture of $Na_4P_2O_7$ and NaOH prepared by dissolving 44.6 g of $Na_4P_2O_7 \cdot 10\ H_2O$ and 4 g of NaOH in 1 liter of distilled water; the $Na_4P_2O_7$ concentrated in the solution corresponded to 0.1 M and the NaOH concentration to 0.1 N. The mixture had a pH of about 13.

The surface (0-15 [20] cm) horizons of the following soils were used for the investigations: a strongly podzolic, an ordinary chernozem, a chestnut, and a sierozem. The soil sample was filled, without preliminary extraction by alcohol-benzol and without decalcification, with one or other $Na_4P_2O_7$ solution and left for 16 to 18 hours after mixing. The soil-solvent ratio was 1:20. The humic and fulvic acid content was determined in an extract carefully filtered off or centrifuged to complete transparency (for a description of the analysis procedure see Section 3 below).

The amount of extracted humic and fulvic acids and the ratios of one to the other are shown in Figure 1. For comparison we have included data on the same soils obtained by the Tyurin method (humic and fulvic acid fractions extracted from decalcified soil by repeated treatment with 0.1 N NaOH solution). Figure 1 also shows the content of humic and fulvic acids extracted by means of a single treatment of non-decalcified soil with a similar solution.

As the graph shows, the yield of humic substances increases with the pH of the $Na_4P_2O_7$ solution. The maximum amount of humic substances was extracted by a mixture of $Na_4P_2O_7$ and NaOH and the amounts in this treatment were in general similar to those obtained by the Tyurin method. In certain treatments the humic to fulvic acid ratio was also similar.

The graduated character of the increase in the amount of humic substances extracted, observable as the pH of the sodium pyrophosphate solution rises, indicates successive replacement by the sodium of the cations bonding these substances. They are completely replaced when the $Na_4P_2O_7$ + NaOH mixture is used. Here the reaction presumably entails the formation of insoluble phosphoric acid salts of calcium, iron (or aluminum), and of soluble humics and sodium fulvates.

The interaction reaction can be schematically represented as follows:

$$1.\quad R(COO)_4Ca_2 + Na_4P_2O_7 \rightarrow R(COONa)_4 + \underset{\text{(In precipitate)}}{\downarrow Ca_2P_2O_7}$$

$$2.\quad [R(COO)_4]_3Fe_4\binom{\text{or}}{Al_4} + 3Na_4P_2O_7 \rightarrow 3R(COONa)_4 + \underset{\text{(In precipitate)}}{\downarrow Fe_4\binom{\text{or}}{Al_4}(P_2O_7)_3}$$

Mobile ferro- or alumino-humic complexes (after the reaction indicated by Aleksandrova [1]) form only when a neutral or weakly alkaline solution of sodium pyrophosphate (pH 7-8.3) is used. This has been shown by the electrophoresis method (3); when the pH of the solution was raised to 9.7 the complexes on the electrophoretic traces appeared less strongly and could not be detected at all when the $Na_4P_2O_7$ + NaOH mixture was used.

On the basis of what has been said previously, we assume that humic substances bonded both with calcium and with non-silicate forms of sesquioxides are extracted with a $Na_4P_2O_7$ + NaOH mixture. These two fractions can be demarcated by comparing the amounts of humic substances extracted with such a mixture and the amounts extracted with a 0.1 N NaOH solution (without decalcification of the soil); if we take it that humic substances which are either free or bonded with non-silicate R_2O_3 forms are separated by the latter solution, then comparison of this amount with the amount extracted with the mixture will give an idea of the amount of humic matter bonded with calcium.

We draw attention to the fact that an $Na_4P_2O_7$ + NaOH mixture extracts roughly 40% to 50% of the total organic soil carbon; the discovery of procedures for separating humic substances firmly bonded with the mineral part of the soil (in the residue) is a matter for further research.

The separation of humic matter from soil without preliminary decalcification by applying a single treatment with $Na_4P_2O_7$ + NaOH mixture greatly simplified the determination of humus composition. We tested this method on the main soil groups and compared the results with those obtained by the Tyurin method. The results are shown below, after a brief description of the method of analysis.[2]

3. Procedure for Rapid Analysis of Humus Composition of Mineral Soils

Table 3 contains data showing that on using a mixture of $Na_4P_2O_7$ + NaOH a single treatment suffices to extract the maximum amount of humic matter and further extraction is redundant. This is true even of highly humic soil with a high exchangeable calcium content (chernozems) and also of carbonate soil (sierozem). The yield of humic acids in both was similar to that obtained by the Tyurin method.

We also tested various soil: solution ratios ($Na_4P_2O_7$ + NaOH). As can be seen from Table 4, the amounts of humic substances extracted were similar whether the ratio was 1:20 or 1:40. For convenience in filtering we worked with a 1:20 ratio.

Now a description of the process of analyzing humus composition by the quick method. From a soil sample prepared by the conventional

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[2] A detailed description of the method can be obtained by writing to the authors.

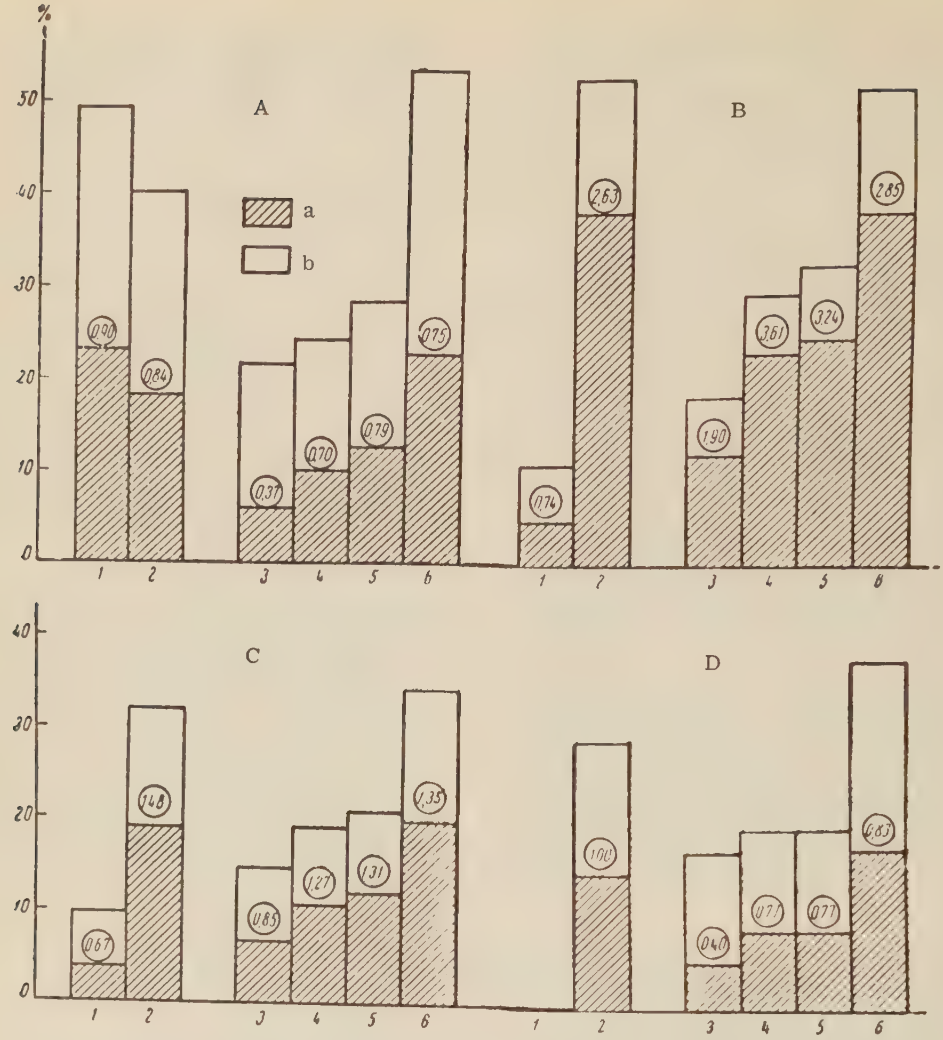

Fig. 1. - Humic and fulvic acid carbon extractable from soil by different procedures (C as percentage of total organic C of original soil). A - strongly podzolic soil. C of original soil = 1.20%; B - ordinary chernozem, C = 5.00%; C - chestnut soil, C = 1.78%; D - sierozem, C = 0.82%: 1 - 0.1 N NaOH; 2 - Tyurin method, sodium pyrophosphate; 3 - pH = 7.4; 4 - pH = 8.3; 5 - pH = 9.7; 6 - $Na_4P_2O_7$ + NaOH mixture, pH about 13: a - humic acid C; b - fulvic acid C; circled figures indicate humic to fulvic acid C ratio.

procedure (removal of small roots and other plant residues, pulverization of the soil and seiving through a 1 mm mesh), a 5 g sample was taken and placed in a conical 250 ml flask; at the end of the working day 100 ml of freshly-prepared $Na_4P_2O_7$ + NaOH mixture was poured on to this sample (for the method of preparing this mixture see Section 2). The flask was tightly covered with a rubber stopper to keep it from atmospheric CO_2, the contents were carefully mixed and left over night. In the morning the contents of the flask were agitated and transferred in their entirety to a funnel with an ordinary paper filter 16-17 cm in diameter set in the cone of a dense (blue winding) filter.

If the first portions of filtrate were cloudy they were put through the filter again; if the solution continued to give a cloudy filtrate it was repeatedly passed through the same filter with the soil. Once a clear solution started to appear it was collected in a dry receiving flask. When the $Na_4P_2O_7$ + NaOH mixture was used, peptization of the soil was less marked than when the $Na_4P_2O_7$ solution alone was used. In all cases, however, it was essential to see that the solution was transparent.

Filtration can be replaced by centrifuging. With strongly humified soils such as chernozems it is sufficient to filter off only part of the extract (about 50-60 ml); with poorly

Table 3

Amount of humic acid C extractable from soils by various numbers of treatment with $Na_4P_2O_7$ + NaOH mixture (% soil weight)

Soil depth, cm	% weight C	Humic acid C extractable with $Na_4P_2O_7$ + NaOH mixture		Humic acid C extracted by Tyurin method
		Single treatment	Four treatments	
Ordinary chernozem, plowed				
0—20	5,00	1,85	1,75	1,87
Sierozem, plowed				
0—20	0,82	0,13	0,12	0,12

Note: Comma represents decimal point.

Table 4

Amount of humic matter extractable from soils, varying soil to solvent ratio ($Na_4P_2O_7$ + NaOH), soil weight

Soil	% weight C	Ratio of soil to solvent	Total organic C in extract	Humic acid C	Fulvic acid C
Ordinary chernozem	5,00	20	2,50	1,85	0,65
		40	2,45	1,80	0,65
Sierozem		20	0,33	0,13	0,20
	0,82	40	0,34	0,14	0,20

Note: Comma represents decimal point.

humified soils the entire solution must be filtered off.

To determine the organic C in the extract, 2-5 ml of dark-colored, 10 ml of light-colored extracts sufficed. The liquid was put into a conical 100 ml flask, 1 N H_2SO_4 was added drop by drop until cloudiness appeared and the liquid was then evaporated in a steam bath to dryness. The C content was subsequently determined by the Tyurin method in Simakov's modification.

In other portions of extract (25 ml of dark-colored, 50 ml of light-colored solutions), put into beakers, humic acids precipitated on acidifying to a pH of about 3. To speed up the coagulation of the gel the beakers were heated to 80°C for 30 minutes and left at room temperature overnight. In the morning the humic acid gel was filtered off by filtering the liquid through a paper filter, washed several times with 0.05 N H_2SO_4 solution in a funnel and there dissolved over solution of boiling 0.05 N NaOH over a graduated flask. After cooling the sodium humate solution was brought to a given volume with distilled water.

The humic acid C was determined in part of this solution and the result subtracted from the total organic C in the extract to give the fulvic acid C content.

The C content in the residue after separation of humic and fulvic acids was calculated from the difference between the amount of organic C in the soil and the total C content in the extract.

The amount of organic matter passing into solution when the soil was treated with 0.1 N H_2SO_4 (Ponomareva method, 4) was calculated in a separate sample. This analysis gave an idea of the solubility of the organic soil substances in mineral acids, a particularly characteristic feature of podzolic soil, red earth and laterites.

Another sample was used to separate the humic and fulvic acids by means of 0.1 N NaOH without decalcifying the soil. Humic substances free or bonded with non-silicate forms of R_2O_3 were separated by this method. The amount of humic matter bonded with calcium could be calculated from the difference between the result and the amount of humic matter separated by the $Na_4P_2O_7$ + NaOH mixture.

We consider it useful to supplement determination of the humus composition by determining the character of the humic acids from optical density, which is an index of the condensation capacity of the aromatic nucleus. The latter, as we know, possesses hydrophobic properties, whereas the presence of lateral chains in the humic acid molecule determine their hydrophilic properties. Since these basic structures occur in the molecule in inverse proportions, the optical density serves not only as an indication of the hydrophobic but, indirectly, acids also, of the hydrophillic properties of the humic also, which determine a number of their important colloid-chemical properties, dispersion, capacity to swell, behavior towards electrolytes and so forth.

In the short method, using the works of Scheffer (15) and Welte (17) we confined ourselves to determining the optical density at two wavelengths, 465 mμ and 665 mμ. The E_4:E_6 ratio, irrespective of the C concentration in the solution, is constant for the humic acids of any given soil group.

From the experience of our work we find that reliable E_4:E_6 indixes (when the thickness of the layer or of the solution in question is 1 cm) are obtained with the following variations in C content per liter of solution. For dark-colored solutions (chernozems and chestnut soils) from 0. 03 to 0. 15 g; for light-colored solutions (from podzolic soils, red earths and sierozems) from 0. 06 to 0. 18 g.

Knowing the C content in the sodium humate solutions (this is determined in the course of the analysis), it is easy to approximate this to the required amount either by dilution (dark-colored solutions) or by careful evaporation in a water bath at a temperature not above 60°C (light solutions).

Using this procedure on different soil groups we obtained the following characteristics E_4:E_6 ratios for the optical density of the humic acids: podzolic soils, 5. 0; dark-gray forest soil, 3. 5; ordinary chernozem, 3-3. 5; chestnut soils, 3. 8-4. 0; sierozem, 4-4. 5; red earths, about 5. The E_4:E_6 ratio for the fulvic acids varied between 6 and 8. 5.

4. Results of Determining the Humus Composition of Various Soil Groups by the Quick Method

The soils investigated were taken from the central taiga subzone, the steppe, dry-steppe, and desert steppe zones and also the humid subtropical and tropical zones. In most cases the determinations were performed for soil profiles where the C content in the samples was not less than 0. 5% of soil weight; this was necessary if reliable results were to be obtained. The data were compared with the results of humus analysis by the Tyurin method

Table 5

Humus composition of Central Taiga soils; Arkangel Oblast' (% total organic C in soil)[a]

Soil depth, cm	% weight C	C extractable with 0, 1 N H_2SO_4	Humic acids	Fulvic acids	$\frac{\text{Humic acid C}}{\text{Fulvic acid C}}$	E_4:E_6	% of total humic acids		Residue
							Free and bonded with R_2O_3	Bonded with Ca	
Strongly podzolic on moraine clay loam									
8—12	1,94	6,4	15,5 14,2	29,4 23,0	0,53 0,62	4,6 4,8	100,0	None	55,1
12—21	0,69	26,8	15,9 9,9	49,3⁺ 21,1	0,32 0,47	—	100,0	"	34,8
21—35	0,45	26,7	8,9 6,7	48,9⁺ 15,5	0,18 0,43	—	100,0	"	42,2
Sod carbonate strongly podzolic on calcareous moraine, forest									
7—15	7,27	7,0	26,5 26,3	25,0 25,2	1,06 1,04	—	100,0	"	48,5
15—24	0,48	11,6	22,9 11,6	29,2 23,3	0,79 0,50	—	64,0	36,0	47,9
Humic — iluvial horizon									
16—28	3,88	35,3	15,5	61,8	0,25	4,8	100,0	"	22,7

[a] Top values in Tables 5, 6, 7 relate to single treatment with $Na_4P_2O_7$ + NaOH mixture without decalcification; bottom values by Tyurin method.

Note: Comma represents decimal point.

Table 6

Composition of soil humus in steppe, dry steppe and desert steppe zones (% total organic C in soil)

Soil depth, cm	% weight C	C extractable with 0.1 N H_2SO_4	Humic acids	Fulvic acids	$\frac{\text{Humic acid C}}{\text{Fulvic acid C}}$	$E_4:E_6$	% of total humic acids		Resi-due
							Free and bonded with R_2O_3	Bonded with Ca	
Ordinary chernozem, plowed Kamennaya steppe, Voronezh Oblast'									
0–20	5,0	3,0	$\frac{37,0}{37,4}$	$\frac{13,0}{14,2}$	$\frac{2,85}{2,68}$	$\frac{3,4}{3,6}$	12,0	88,0	50,0
Chestnut soil, plowed Valuyskaya Exp. Stn. Volgograd (Stalingrad)									
0–20	1,78	5,6	$\frac{19,7}{19,1}$	$\frac{14,6}{12,9}$	$\frac{1,35}{1,48}$	$\frac{3,6}{3,7}$	20,0	80,0	65,7
Sierozem, plowed Tashkent Oblast'									
0–20	0,82	8,5	$\frac{17,1}{14,6}$	$\frac{20,7^{+}}{14,6}$	$\frac{0,82}{1,00}$	$\frac{4,0}{4,0}$	None	100,0	62,2

Note: Comma represents decimal point.

Table 7

Composition of humus in tropical and wet subtropical soils (% total organic C in soil)

Soil depth, cm	% weight C	C extractable with 0.1 N H_2SO_4	Humic acids	Fulvic acids	$\frac{\text{Humic acid C}}{\text{Fulvic acid C}}$	$E_4:E_6$	% of total humic acids		Resi-due
							Free and bonded with R_2O_3	Bonded with Ca	
Red earth, for., chakva									
10–15	7,06	12,2	$\frac{11,6}{19,0}$	$\frac{28,9}{25,7}$	$\frac{0,40}{0,74}$	$\frac{4,9}{5,0}$	100,0	None	59,5
Laterite on shale (tea crop), Vietnam									
0–5	1,73	13,0	$\frac{6,9}{3,8}$	$\frac{30,6^{+}}{19,6}$	$\frac{0,23}{0,19}$	$\frac{5,0}{5,1}$	Not det'd.		62,5
5–18	1,55	12,0	$\frac{8,4}{3,7}$	$\frac{27,7^{+}}{19,5}$	$\frac{0,30}{0,19}$	5,0	"	"	63,9
Margalitic on ash and tuff, forest, Vietnam									
0–13	3,33	1,7	$\frac{21,0}{28,4}$	$\frac{14,7}{16,6}$	$\frac{1,43}{1,70}$	3,5	100,0	None	64,3
13–25	2,89	7,1	$\frac{19,0}{22,1}$	$\frac{18,0}{19,5}$	$\frac{1,06}{1,13}$	$\frac{3,5}{3,4}$	100,0	"	63,0
25–40	1,20	10,4	$\frac{8,3}{4,5}$	$\frac{25,8}{24,6}$	$\frac{0,32}{0,18}$	$\frac{5,7}{5,0}$	100,0	"	65,9

Note: Comma represents decimal point.

(fraction I of humic matter isolated by repeated treatment with a 0.1 N NaOH solution after alcohol-benzol extraction and decalcification of the soil). It was of course impossible that the results of the two methods should coincide completely, since in the quick method treatment with a $Na_4P_2O_7$ + NaOH mixture was applied without preliminary alcohol-benzol extraction and without decalcification. The substances extracted by these procedures and isolated, in the Tyurin method, into separate groups, fall into the fulvic acid group when the quick method is used; if they are present in large amounts they substantially raise the humic matter content in these acids, as can be seen from Tables 5 and 7 (values with + sign relating to podzolic soils, red earth and laterite). Despite the discrepancy in certain indixes the main results of the two methods on the whole agree well.

The podzolic soil humus is characterized by a high content in substances extracted with 0.1 N H_2SO_4, by the predominance of fulvic over humic acids and by a humic to fulvic C ratio not exceeding 0.5. The wide $E_4:E_6$ ratio indicates a relatively poor condensation capacity of the humic acid aromatic nucleus. The humic acids of podzolic soils have a correspondingly high dispersion capacity, mobility and resistance to electrolytes. The humic acids are for the most part free or bonded with non-silicate forms of R_2O_3.

These characteristics, typical of podzolic soil humus, are most evident in the humus-illuvial horizon and in somewhat milder form in sod-carbonate strongly podzolized soil on calcareous moraine, where signs of sod-formation are apparent in the reduced amount of substances extractable with 0.1 N H_2SO_4 and in the increased humic acid content, giving a humic to fulvic acid C ratio approaching unity.

Table 6 gives the values for the humus composition of steppe, dry-steppe and desert steppe soils. Chernozem humus is characterized by stability, as is indicated, in particular, by the low content of substances extractable with 0.1 N H_2SO_4. The humus contains a large amount of humic acids, which clearly predominate over fulvic acids (wide humic to fulvic acid C ratio). The humic acids have a condensed aromatic nucleus ($E_4:E_6 = 3.4-3.5$) and are correspondingly hydrophobic, poorly dispersed, of low mobility and non-resistant to electrolytes; in chernozem they are bonded primarily with calcium.

Elements of lower stability appear in chestnut soil humus, which have a lower humic acid content and a narrower humic to fulvic acid C ratio than do the chernozems. A tendency towards lower condensation capacity of the aromatic nucleus can be observed. These characters, indicating loss of stability are more apparent in sierozem humus.

Table 7 gives the humus values for wet subtropical and tropical soils. Red earth and laterite shows a high content in substances extractable with 0.1 N H_2SO_4, a low content of humic acids and a clear predominance of fulvic acids, the humic to fulvic acid C ratio being well below unity. The wide $E_4:E_6$ ratio (nearly 5.0) indicates relatively poor condensation capacity of the aromatic nucleus in red earth and laterite humic acids, which have a correspondingly high dispersion capacity, mobility and resistance to electrolytes.

In a number of these soils a margalitic soil can be distinguished. In the humus of this soil's surface horizons we find elements of stabilization, manifested in the low content of substances extractable with 0.1 N H_2SO_4 and the higher content of humic acids (humic to fulvic acid C ratio above unity). The humic acids are characterized by the presence of a condensed aromatic nucleus ($E_4:E_6 = 3.5$). The humus in the bottom horizon of this soil, however, resembles that in laterite.

Attention is drawn to the fact that in all the soils the $E_4:E_6$ ratio for humic acids extractable with 0.1 N NaOH (Tyurin method) and by $Na_4P_2O_7$ + NaOH mixture (quick method) were similar. This once again confirms the contention that the humic acids extracted by either method are of similar nature.

Summary

The authors sought to devise quick methods of determining the humus composition of mineral soils. This problem can be solved in two ways.

1. The Tyurin method can be shortened by omitting determination of the group of substances extractable with an alcohol-benzol mixture and the fraction II of humic substances, extracted by alternate processing with 0.1 N H_2SO_4 and 0.1 N NaOH.

The characteristic features of the humus in different soil groups are retained despite these omissions.

2. We devised a quick method, using a $Na_4P_2O_7$ + NaOH mixture (pH about 13). A weighed sample of soil treated once with this mixture without alcohol-benzol extraction and without decalcification extracted an amount of humic matter similar to that obtained by the Tyurin method (as indicated by fraction I extracted by multiple treatment with 0.1 N NaOH solution after decalcification).

The pattern of humus formation in different soil groups, established by Tyurin, is thus confirmed.

3. To obtain a more detailed picture of the humus we recommend determining in individual weighted samples the amount of organic matter passing from the soil into a 0.1 N H_2SO_4 solution and also the amount of humic matter extractable with a 0.1 N NaOH solution from non-decalcified soil.

4. The nature of the humic acids is given by the optical density.

The paper gives the results of using the methods recommended by us to study the humus of various soil groups.

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METHODS

CHARACTER AND SEQUENCE OF THE ENTRY OF ELEMENTS INTO A CARBON ARC FLAME IN SPECTRAL ANALYSIS OF SOIL

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Evaporation of a test sample of salts of plant from the carbon electrode channel in quantitative soil spectral analysis is accompanied by a change in the rate at which the elements enter the discharge zone and by their fractionation, as has been noted by a number of investigators in regard to other test subjects (2, 3, 4, 5, 8, 9).

The gradual alteration in the composition and concentration of the elements in the arc plasma upsets the evaporation and excitation temperatures, leads to continuous variation of the spectral lines and often causes them to appear at different intervals in the burning time of the arc.

Elements possessing very high volatility and very low ionization potentials (Li, Na, K, Zn, Pb and others) for the most part lower the flame temperature of the arc. The sensitivity and accuracy of quantitative spectral analysis of soils and other subjects with variable chemical and mineralogical composition depend largely on the rate of evaporation of the test sample's components and the character of the evaporation processes.

It is scarcely possible to make valid methodological recommendations for the quantitative determination of micro-elements in soil and plant ash without studying the element-evaporation and spectral-excitation processes and the factors influencing them. These processes are influenced by the chemical and mineralogical composition, the physical properties (for example, dispersion) of the soils and standards and the regime of the excitation source. As Abramson and Mandel'shtam (1) point out, there are now spectral-excitation sources which very faithfully reproduce the conditions of atom excitation, so that the main reason for arc instability is variation in the discharge plasm composition time. Until reliable methods of stabilizing the temperature of a carbon arc and reducing the effect of fractional evaporation of the elements in the test sample are found, systematic errors in analyzing substances of complex and variable composition will always occur (6).

Published information on the nature and evaporation rate of elements relates primarily to geological samples (2, 3, 4, 5, 8); the lack of such information in regard to soil makes the quantitative spectral analyses of soil much more difficult.

A further complication in selecting optimum conditions for soil and plant ash analysis is that elements of various excitation and ionization potentials are present in soil along with elements of varying volatility.

Elements from soil and standard samples of complex composition will, on evaporation of the sample in an electric arc, enter into discharge from the carbon electrode channel in a definite order, corresponding to the order of volatility. The fractional distillation effect can be traced from the evaporation curves.

We traced the evaporation curves (Mg; Al; Ca; Ti; V; Cr; Mn; Fe; Co; Ni; Cu; Zn; Mo; Pb) from soils and standards in an alternating current arc, photographing the spectrum every thirty seconds of arc burning time.

The following were used as analysis lines

Mg—2782. 9Å
Al—3050. 1Å
Ca—3158. 8Å
Ti—2956. 1Å
V—3185. 4Å
Cr—3014. 7Å
Mn—2949. 2Å
Fe—3265. 0Å
Co—3453. 5Å
Ni—3414. 7Å
Cu—3274. 0Å
Zn—3345. 0Å
Mo—3170. 3Å
Sn—3175. 0Å
Pb—2833. 1Å

In the first series of tests, the results of which are given below, the experiment conditions were as follows.

The source of excitation was an alternating current arc fed from a 10 amp DG-1 generator 0-6 mm at a distance of 2. 5 mm.

ISP-22 spectrograph, width of slit 10 μ, height 1 mm, revolving disphragm groove 5 mm. Plastic cassette was moved manually one mm each 30 sec. Fifteen mg sample (soil, standard), were placed in a concentric groove at the surface of the lower carbon electrode; the top carbon electrode was sharpened into a truncated cone. The blackened lines were determined through the objective of a MF-2 micro-photometer. The absolute blackened lines (S) were taken into account. A large number of evaporation curves from various soils

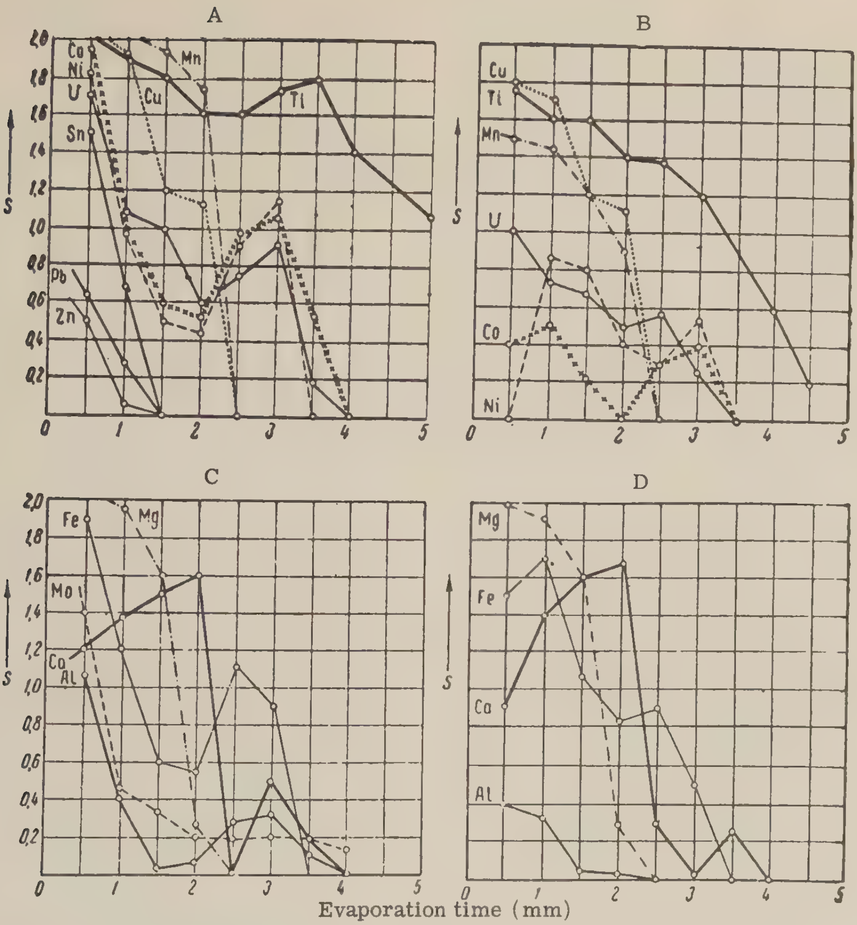

Fig. 1. - Relationship between blackening of micro-element lines and evaporation time from: A and C standards; C and D soils.

and standards was constructed. Below we give the data relating to a mountain meadow soil sample and standard, the total composition and micro-element content of which are shown in Table 1.

Under the effect of a high electrode temperature the soil and sample not only evaporated but also interacted with the material of the electrode with gases (CO and others) formed in the burning of the arc. The soil (standard) components may interact with one another and the elements will then evaporate from the newly-formed compounds. All the blackening-time graphs reproduced show that the volatile elements such as zinc, lead and tin (Fig. 1-A) evaporate first. The first and last times of element entry into the flame were identified from the appearance and disappearance only of the analytical lines of known sensitivity.

This, together with some variation in the content of elements in the soils and standards, means that our determinations of the rate and character of the elements' volatility is tentative; but the reservation does not detract from the substantially regular sequence of evaporation discovered, especially as this is on the whole confirmed by the element volatility sequence traced by Rusanov (5).

The elements decomposed in the following order of decreasing volatility:

[Zn; Pb; Sn] Mg; [Mn; Cu] [Fe; Co; Ni; V] Ca;
Al; Cr; Ti; Mo
$\longrightarrow$
Decrease of volatility

The evaporation sequence of the bracketed elements (those of similar volatility; for example, manganese and copper) and of elements in the iron group (Fe, Co, Ni, V) may vary from one soil or standard to another. In the case of elements of similar volatility this is due to differences in the chemical and mineralogical composition of the samples and standards and to the composition and properties of the compounds formed in the arc.

Note that decreased volatility coincides, in some elements (Zn, Pb, Sn, Mn, Cu, Fe, Co, Ni, V, Ti, Mo) with the rise in boiling point of

Table 1

Total content of macro- and micro-elements in soils and standards, % ignited weight

Sample	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Na_2O	K_2O	Ni $n \cdot 10^{-3}$	Co $n \cdot 10^{-3}$	Cr $n \cdot 10^{-3}$	V $n \cdot 10^{-3}$	Mn $n \cdot 10^{-3}$	Ti	Cu $n \cdot 10^{-3}$	B $n \cdot 10^{-3}$	Mo $n \cdot 10^{-3}$	Pb $n \cdot 10^{-3}$	Sn $n \cdot 10^{-3}$	Zn $n \cdot 10^{-3}$	Ba $n \cdot 10^{-3}$
Standard Profile 215 A_1 (0-10 cm) of mountain-meadow fine clay loam on slate shales	64,0 66,4	7,0 8,1	25,0 26,1	1,0 1,9	2,5 2,3	0,5 Not det'd.	0,5	11,2 5,01	10,0 2,57	3,0 1,41	3,0 1,80	60,0 9,9	2,0 1,0	12,0 5,75	10,0 Not det'd.	10,0	20,0	20,0	10,0	18,0

Note: Comma represents decimal point.

Table 2

Boiling points of metals and their oxides

Boiling point	Elements														
	Zn	Pb	Sn	Mg	Mn	Cu	Fe	Co	Ni	V	Ca	Al	Cr	Ti	Mo
Metal (T^oK) Metal oxides	907 —	1525 1744 1472	2227 1700	1107 3100 ±300	1900 2151 3100 ±100	2595 —	3000	2900 3135 1805[a] ±20	3005 3177 —	3000 2245	1487 3500 ±200	1800 3500 ±200	2482 2437 [b]	3400 3100 [c] ±300	4804 1251[d]

Note: [a] Melting point on further heating breaks down into Co + 0.

[b] Breaks down at roughly 3000 ± 300°.

[c] Ti_2O_5; TiO_2 breaks down at 3000°

[d] MoO_2 at 2000°C breaks down to Mo + MoO_3.

the corresponding metals (Table 2). No such coincidence is observable in the other group of elements (Mg; Ca; Al; Cr).

Rusanov (5) has shown that elements which do not possess the capacity of forming stable compounds in the arc (carbides, oxides and others) follow an order of volatility corresponding to the order of rise in boiling point of their metals. Mg, Ca, Al and Cr, as one would expect, evaporate in the form of oxides.

No important difference in the volatility of particular elements from the soil and from the standard was detected.

The evaporation curves for individual elements show that zinc evaporates very rapidly (Fig. 1-A). This element has the lowest boiling point 1180°K. Zinc evaporated completely both from the standard and from the soil in one minute.

The next elements in decreasing order of volatility were lead and tin. The intensity of their lines, which reach their peak value in the first few seconds of burning, decreases uniformly to zero. Evaporation is complete after 1.5 min. Rusanov (5), evaporating zinc, lead and tin oxides, sulfides, carbonates, phosphates and silicates from a carbon electrode, showed that all these elements were reduced in the process, forming regulines of free metal. The rate at which the elements entered the arc flame depended on the rapidity with which the compounds were reduced to the free element and the evaporation time of the metal from the regulines. The presence of third elements too plays an important part in the rate of entry of the other components. The less volatile compounds (of Mn, Cu, then Fe, Co, Ni and others) enter discharge usually after evaporation or at the end of evaporation of Zn, Pb and Sn, and this must always be taken into account and used in quantitative spectral analysis of soils and plant ash. The advantages given by the difference in evaporation rate of the different elements are used in quantitative spectral analysis of geological subjects; this method has proved itself in practical work (8, 9).

After the readily volatile elements the relatively non-volatile elements evaporate. In order to volatility magnesium follows close on Zn, Pb, and Sn. It has a comparatively low boiling point (1360°K), but as Rusanov's research (5) has shown it forms stable magnesium oxide, which has low volatility, in the process of evaporation of its compounds. The entry of magnesium from soils and from standards was identical. In the first few seconds of burning the intensity of the magnesium lines increased sharply, reaching a maximum in the first minute. The subsequent decrease in intensity was similarly abrupt. Evaporation was complete after 2.5 min. The relative position of Mg, Mn and Cu in order to volatility varies and depends on the total chemical composition of the samples and standards.

The evaporation curves for copper and manganese are similar to those for magnesium. Cu and Mn evaporate completely after 2.5 min (Fig. 1A and B).

Next in decreasing order of volatility come elements of the iron group. These have similar properties, the same boiling point and the same evaporation, as is shown by the results (Fig. 1-A, B, C, D). Co, Ni and V, if present in micro-amounts, enter simultaneously with iron present as a macrocomponent. The possibility of Fe, Ni, Co melts forming, with subsequent evaporation of these elements from the new compounds, is not excluded.

Two intensity peaks in the evaporation process are characteristic of this group of elements under the given conditions of evaporation and spectral-generation of soils. The first and highest occurs in the first minute of burning, the second in the third minute. The variation in intensity of the element lines with time was similar for the soils and for the standards, sometimes falling to zero at different intervals in burning time, to reappear later. This must be kept in mind in analyzing soils and other test subjects.

Rusanov (5), evaporating minerals, ores and standard mixtures of oxides, sulfides and silica salts in a DC arc from the anode aperture, found that nickel, cobalt and iron entered uniformly and simultaneously. The evaporation curves for these elements are evidently superimposed one upon another, irrespectively of their quantitative ratios and of the chemical composition of the test sample. The mineral evaporation curves do not, as a rule, give two volatility peaks for elements of the iron group, as in the case of soils. The reason for this is not yet known. Presumably free oxides and other compounds of iron are present simultaneously in soil.

Elements of the iron group come midway in order of volatility, evaporating completely after 3.5 min under the conditions of our experiment.

The slowest to evaporate are chromium, titanium and molybdenum (Fig. 1-A and C). The very slow evaporation of these elements in the carbon arc is connected with the formation of their carbides, which have a very low vapor pressure even at high temperatures. In practice evaporation of these elements is not complete even after 5 min of burning.

Summary

In order to work out methods of quantitative emissive spectral analysis of soils, plant ash and similar samples of complex composition, it is essential to investigate the processes of evaporation and spectral-generation of the chemical elements to be determined, in relation to the regime of the source and the composition of the samples and standards.

In descending order of volatility in a 10 amp DC carbon arc, the elements from soils (standards) fell into the following groups: [Zn, Pb, Sn] Mg[Mn, Cu] [Fe, Co, Ni, V] Ca, Al, Cr, Ti, Mo.

Optimum conditions of analytical procedures in determining the content of elements in soil and plant ash should be chosen in the light of

the volatility and evaporation sequence.

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DETERMINATION OF MOBILE ALUMINUM IN SOILS

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According to modern views, the exchangeable ions in soil owe their existence to the continuous discharge in finely-dispersed mineral and organic particles at the surface. There are grounds for believing that there are at least three sources of these discharges (10).

1. Isomorphic substitution in the crystalline structures of alumino- and ferro- or ferrisilicates. 2. The presence of ionogenic groups on the surface of particles (silanolic in the case of the mineral part, carboxylic, phenolic and amino in the organic part). 3. Disassociation of compounds adsorbed at the surface.

A special place among exchangeable ions belongs to aluminum, which in some cases can pass into the exchanged state in the form of trivalent ions from the octahedral and tetrahedral crystalline lattices of silicates. Aluminum forms complex hydroxyal ions as well. The state of the aluminum ion influences the behavior of the colloid as a whole, for change of its coordination number or transition to the exchangeable state affect the number of discharges and consequently the total content in exchangeable ions; the stability of the soil silicates, the acid-base properties of the soil or, in the most general form, its proton regime also depend on the state of the aluminum (7).

Particular importance therefore attaches to the determination of aluminum and to making allowance for changes in its state and degree of mobility, for the purpose of assessing the range either of the acid or of the alkaline reactions of soil (podzol, other strongly leached soils solodi in the former case, various alkaline soils in the latter).

Determination of mobile aluminum in soils actually involves two stages: primarily, transfer of the mobile aluminum from the soil complex into solution and secondly, its determination in the solution.

The commonest method in current use is Sokolov's (5). The soil mobile aluminum enter into solution by agitating the soil sample with a 1 N solution of KCl. Total exchangeable acidity is determined by titrating in potassium chloride extract and the free acidity is then determined after addition of sodium fluoride. The difference is the amount of mobile aluminum. Potassium chloride solution, however, is not a buffer and its pH varies greatly on agitated with the soil sample, depending on the nature of the soil under study. The reaction of the medium on transfer of the aluminum into solution therefore varies from one natural soil group to another. Since aluminum mobility in the soil complex, like the solubility of its compounds, depends largely on the acidity of the medium, the portion of aluminum which passes into solution from the soil sample will naturally vary from one case to another.

Table 1 illustrates the great significance of the soil acidity in the transfer of available aluminum into solution.

We investigated the variation in the reaction of 1 N KCl by agitating it with samples of various soils. The results are given in Table 2. From these it follows that the pH of the salt extract varies within a wide range, from 4.35 in the case of sod-podzolized surface-gleyed soil to 7.35 in the case of dark chestnut soil, in other words, over a range of 3 units. This means, according to the data of McLean and colleagues (8) (Table 1), that with such a variation in the acidity of the medium the amount of aluminum passing into solution, even from the same soil, may vary by a factor of almost 4.

Treating a soil with 1 N KCl for the purpose of transferring the mobile aluminum into solution does not, consequently, mean that identical conditions are produced; the values obtained by this method for different soil groups are therefore not comparable with one another.

McLean et al. studied the possibility of using $BaCl_2$, $(CH_3COO)_2Ba$, CH_3COONH_4 and mixtures of these for extracting aluminum from soil. They reached the conclusion that only a buffer solution of CH_3COONH_4 and CH_3COOH mixture gave satisfactory results. The unsuitability of the other solutions was evidently due to their low buffer capacity. To extract aluminum the authors recommend using an ammonium acetate buffer solution with a pH of 4.8. More acid solutions may break down the crystal lattice, while in less acid mediums a

Table 1

Relationship between amount of aluminum passing from soil into solution and the pH (after McLean, et al. [8])

pH	Cambridge soil		Tilsit soil	
	Amt. of mobile aluminum, meq/100 g of soil	$\frac{\Delta A}{\Delta pH}$	Amt. of mobile aluminum, meq/100 g of soil	$\frac{\Delta Al}{\Delta pH}$
5,5	7,0	—	0,36	—
5,2	9,3	7,7	0,45	0,3
5,0	11,9	13,0	0,63	0,9
4,8	17,2	26,5	1,19	2,8
4,5	22,6	18,0	1,60	1,3
4,2	27,7	17,0	2,29	2,3
4,0	30,2	12,5	2,55	1,3
3,0	32,1	1,9	3,33	0,8

Note: Comma represents decimal point.

smaller amount of aluminum enters solution. Maximum leaching is observed precisely in the pH range 4.8-5.0. This can readily be seen from the Δ Al/Δ pH amount calculated by us and given in Table 1 (columns 3 and 5) (that is, the amounts of mobile aluminum passing into solution when the reaction of the medium changes by one unit pH).

Consequently, buffered ammonium acetate solution with a pH = 4.8 creates optimum condition for extracting mobile aluminum from soil complex, therefore it is recommended for use.

Comparison of pH values of buffered ammonium acetate solution with soil in 1:5 delutions before and after shaking on a rotar for one hour is given in Table 2. The pH values were measured with a glass electrode. These data show that using 1 N KCl for obtaining mobile aluminum from soil does not give satisfactory results because reagent does not have sufficient buffering capacity. In this respect ammonium acetate buffer is favorable for the pH value of solution changes only a 0.15 unit after shaking with a strongly calcareous soil.

From the foregoing, it is obvious that ammonium acetate buffer solution with pH 4.8-4.85 has in fact a considerable advantage over a 1 N KCl solution and must be recommended for determining mobile aluminum in soil.

The aluminum thus transferred into solution can be determined by any of the existing methods. We recommend for these purposes complexometric titration, a rapid method yielding easily

Table 2

Resistance of pH of 1 N KCl solutions and of ammonium acetate buffer solution before and after treatment of various soils

Soil, location and depth	pH			
	1 n KCl		1 n $CH_3COONH_4 + CH_3COOH$	
	Original solution	After treat of soil	Original solution	After treat. of soil
Sod-podzolized surface gleyed, Stanislavskiy Oblast' 15–20 cm				
Plot No. 1	5,55	4,35	4,85	4,85
" No. 2	5,55	4,85	4,85	4,85
" No. 3	5,55	4,65	4,85	4,85
" No. 4	5,55	4,70	4,85	4,85
" No. 5	5,55	4,45	4,85	4,85
Dark chestnut solodized. Belozerskiy rayon., Kherson, 0–10 cm	5,55	4,70	4,85	4,85
Dark gray podzolized steppe Khar'kov Oblast'. 0–25 cm	5,55	4,85	4,85	4,85
Solonetz crust eluvial. Virgin land. Kremenchugskiy rayon, Poltava Oblast' 0–7 cm	5,55	5,60	4,85	4,85
Chernozem, thick, weakly leached, fine clay loam, Rogan', Khar'kov Oblast' 0–20 cm	5,55	5,85	4,85	4,85
Chernozem, thick, leached, fine clay loam. Khar'kov Oblast' 5–10 cm	5,55	5,85	4,85	4,85
Dark chestnut, fine clay loam. Berdyanskoye forest 100-120 cm (effervesces from acid)	5,55	7,30	4,85	4,85
Same, 270-300 cm (effervesces violently fr. acid)	5,55	7,35	4,85	5,00

Note: Comma represents decimal point.

producible results and enabling iron to be determined at the same time.

According to Shvartsenbakh (6), in the case of the Al^{+++}, the formation of a complex with the trilon B is slowed down, with the result that direct titration cannot give a positive result. Shvartsenbakh recommends back titration, with the necessity of heating to the boiling point to complete the reaction. This is necessary in determining aluminum in soil extracts, since the trilon B is added to the buffer solution and this can entail formation of multinuclear aluminum hydroxide complexes which are not completely broken down by the trilon B; this can make the results too low unless heating to the boiling point is performed. Bashkirtseva and Yakimets (2) also confirm that on heating, a completely adequate rate of trilon B complex formation with the aluminum ions is achieved. These authors (3), investigating the possibility of complexometric determination of aluminum ions in various materials from aluminum factories, carefully studies interference from incidental ions present in the solution and indicated ways of eliminating these. To eliminate the influence of magnesium and calcium they recommend titrating in a medium with pH of 4. 8. At this acidity of the solution, according to their data, the magnesium ion does not have any effect on the course of the titration and the permissible calcium ion content is 50 mg per 100 ml of solution.

Iron ions interfere with the aluminum determination, but, on the one hand, the amount iron can be first determined in the first extract by direct titration with a solution of trilon B at low pH values (about 2, acidified with HNO_3) and on the other hand, when soil is treated with an ammonium acetate buffer solution of pH 4. 8 only traces of iron pass into solution, and then only from soils rich in iron.

The K^+ and Na^+ does not interfer with titration nor does the Cl_1, SO_4^{---} and NO_3^-. A PO_4^{---} content of up to 30 mg in 100 ml of solution also permits complexometric determination of aluminum. Consequently, the cations and anions usually contained in soil extracts are no hindrance to complexometric determination of the aluminum ion in an ammonium acetate solution of pH 4. 8.

Sodium sulfosalicylate is suggested by Bashkirtseva (1) as the indicator in inverse titration of the Al^{+++} with $FeCl_3$ solution. Shvartsenbakh (6) recommends salicylic acid for this titration; some authors use also sulfosalicylic acid (4).

Since the amount of PO_4^{---} in our soil extracts was small we were able to use any of the above-mentioned indicators. As we expected, only ammonium or sodium sulfosalicylates gave a sufficiently clear transition of color in the soil extracts. Addition of salicylic acid, both of dry and of alcohol solution, during titration of the soil filtrate, did not produce an abrupt change of color at the equivalence point, as was observed in titration of standard solutions. The color transition is so gradual that salicylic acid cannot be used as an indicator in titration in soil solutions.

An attempt at back titration in determining aluminum in soil extracts by a solution of zinc sulfate in the presence of dithiazone (as indicator) did not yield positive results, nor did back titration with solutions of zinc sulfate and magnesium sulfate in the presence of black T eriochrome as indicator.

We recommend performing the determination of soil mobile aluminum, which went into solution with the aid of an ammonium acetate buffer of Ph 4. 8, by complexometric titration with a $FeCl_3$ solution in the presence of sodium sulfosalicylate as indicator. The mean relative error in the determination as compared with the weight method is 0. 038 meq per 100 g of soil if the soil is rich in aluminum.

Our laboratory determination of mobile aluminum soil is performed as follows:

To 30 g of pulverized soil, passed through a 1 mm mesh sieve, 150 ml of ammonium acetate buffer solution, pH 4. 8, are added and agitated in a rotator for 1 hr. The soil extract is filtered off into a 200 or 250 ml volumetric flask and the sediments washed several times with the buffer solution until a mark on the volumetric flask is reached. To 50 ml of filtrate 3-5 ml of 0. 05 m trilon B solution are added (3 ml for soils with a low mobile aluminum content, 5 ml for aluminum-rich soils) and the solution is left to stand for 5 to 10 min., heated to boiling point and then cooled.

About 1 ml of indicator (sodium sulfosalicylate) is added to the cooled solution and the excess trilon B is titrated with a 0. 025 M solution of $FeCl_3$ until a brown coloration of the iron sulfosalicylate appears. The aluminum content in grams per 100 g of soil is calculated from the formula

$$Al = \frac{(V_{trB} - V_{FeCl_3} \cdot K) \cdot T_{tr} \cdot b \cdot 100}{30}, \text{ where}$$

V_{trB} is the volume in ml of the trilon B added to the solution; V_{FeCl_3} is the volume in ml of the $FeCl_3$ which has gone to back titration; K is the ratio between the trilon B and $FeCl_3$ solutions:

$$K = \frac{V_{trB}}{V_{FeCl_3}}$$

b is the conversion coefficient of the volume taken for titration to the total volume of soil extract: T_{tr} is the trilon B aluminum titer.

A standard aluminum solution is prepared by dissolving alumino-potassium alum at the rate of 0.02 m in one liter of distilled water acidified with approximately 1. 0-1. 5 ml of concentrated H_2SO_4.

The ratio between the trilon B and the standard solution is established in the same way as aluminum is determined with necessary addition of a buffer solution. The aluminum content in the standard solution is determined gravimetrically.

The indicator, a sodium sulfosalicylate solution (2), is produced by dissolving 10 g of sulfosalicylic acid in 60 ml of distilled water, with subsequent neutralization with 2 N solution of NaOH to acid reaction to methyl orange (up to 70 ml of sodium hydroxide).

To obtain the ammonium acetate buffer solution of pH 4.8 a 1 N solution of ammonium acetate in 400-500 ml of distilled water is obtained and 50 ml of glacial acetic acid are added and the volume brought to 1 liter. Such a buffer mixture must have a pH of 4.8.

A 0.025 M of $FeCl_3$ is prepared and dissolved in 200-300 ml of distilled water, acidified with 20-25 HCl (specific gravity 1.19) and brought up to the mark in the liter flask with water.

Conclusion

1. It is shown that 1 N KCl solution, because of its low buffer capacity, cannot be recommended for obtaining mobile aluminum from the soil in solution. For this purpose it is recommended that an ammonium acetate buffer solution with pH 4.8 be used.

2. A method is given for determining mobile aluminum in soil extract by the complexometric method (with trilon B) with back titration using $FeCl_3$ solution and sodium sulfosalicylate as indicator.

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A CONTRIBUTION TOWARDS COMPLEXOMETRICAL DETERMINATION OF EXCHANGEABLE CALCIUM AND MAGNESIUM IN SOILS[1]

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Verigina's method (2) is the simplest of the recently described complexometric methods of determining calcium and magnesium in soil extracts (2, 5, 6). On checking this method, however, we have discovered certain defects. The most important of these is that on tritration with trilon B (disodium salt of ethylene-diamine tetraacetic acid) in the presence of black ET-00 chromogen or fast mordant blue a calcium-magnesium balance which is slowly established.

For this reason the color of the titrated solution often alters again, on standing from blue to violet, so that further titration becomes necessary and difficulties arise in accurately establishing the equivalence-point. Further, in direct determination of calcium with murexide, when sizeable amounts of magnesium are present in the solution, partial coprecipitation of calcium with the magnesium oxide hydrate is possible (4), with the result that the calcium determination is incomplete. Lastly, in determining calcium and magnesium in NH_4Cl extract, direct calcium determination is regarded as impossible; on the other hand, according to our data, the direct determination of magnesium, which is recommended to perform after the calcium, has been precipitated in the form of an oxalate (1) or sulfate (6) and does not yield satisfactory results and requires prliminary filtration.

We tested various modifications of complexometric titration and made a comparative investigation of the accuracy of complexometric and "classical" methods (the volumetric oxalate-permanganate method for calcium, the gravimetric pyrophosphate method for magnesium.)

The above-mentioned defects of the method can be eliminated, without detriment to the simplicity of the analysis, by making the following changes:

1. For determination of the total calcium-magnesium the solution under investigation is first heated to 70°-80°C (when steam appears), the necessary reagents are added (Na_2S, hydroxylamine, buffer solution, indicator), and the solution is at once titrated. In the hot solution chemical equilibrium is rapidly established; there is a distinct change of color at the equivalance-point and the former color does not return when the solution is left standing.

2. To prevent coprecipitation of calcium with magnesium in direct determination of calcium with murexide, 2 ml of 0. 5 N Na_2CO_3 solution are first added to the test sample (before addition of NaOH. The calcium then precipitates in the form of $CaCO_3$, forming a separate phase, which dissolves in the course of subsequent titration. The possibility of calcium coprecipitation with $Mg(OH)_2$ is thus eliminated and complete calcium determination is ensured.

3. The difficulties in direct determination of calcium with murexide in NH_4Cl extract are due to the high buffering character of NH_4Cl solutions in the alkaline region. This means that to obtain the required pH (about 12), 0. 5 ml of 10% KOH or NaOH must be added to each mm of the filtrate taken for analysis (using 1 N NH_4Cl solution). This ensures the necessary conditions for a distinct change of color of the indicator (murexide) when the equivalence-point is reached.

For comparative evaluation of the accuracy of the results obtained a) by the complexometric method, modified as indicated previously, and b) by the classical methods, we used the method of additions. To the NaCl and NH_4Cl soil extracts were added titrated solutions of calcium and magnesium salts at the rate of 5. 19 meq of calcium and 2. 69 meq of magnesium per 100 g of soil. The calcium and magnesium content in the initial extracts and in the extracts to which Ca and Mg had been added was determined by complexometric titration of the trilon B (calcium and total Ca + Mg by direct titration magnesium variously) and also by the classic methods (calcium by the oxalate-permanganate and magnesium by the pyrophosphate methods). The table shows the results of these determinations on four soils: 1) a weakly podzolic, slightly cultivated sandy loam; 2) a weakly podzolic, well cultivated fine clay loam; 3) a podzolic-gley, fine clay loam, slightly cultivated; 4) a

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[1] In the opinion of the editors the authors' condition that Ca can be determined with murexide in the presence of ammonium salts requires experimental verification even when large amounts of NaOH are used. Editor.

Table 1

Analysis results for NH_4Cl soil extracts, meq per 100 g of soil
a — complexometric titration; b — classic method

Soil	Initial extracts		Extracts with addition of Ca and Mg		Difference (addition found)		Amount found, as % of addition	
	a	b	a	b	a	b	a	b
Total calcium and magnesium content								
Slightly podzolic, slightly cultivated sandy loam	6,7	7,1	14,4	15,0	7,7	7,9	98	101
Slightly podzolic, well cultivated fine clay loam	21,4	20,8	29,1	28,3	7,7	7,5	98	95
Slightly cultivated podzolic gley fine clay loam	9,2	8,2	16,7	16,5	7,5	7,2	95	92
Cultivated podzolic gley fine clay loam	12,5	12,8	20,4	20,6	7,9	7,8	101	99
			Average		7,7± ±0,2	7,6± ±0,4	98± ±2	96± ±4
Calcium content								
Slightly podzolic, slightly cultivated sandy loam	6,0	5,6	11,1	11,0	5,1	5,4	99	104
Slightly podzolic, well cultivated fine clay loam	17,5	15,7	22,7	20,6	5,2	4,8	101	93
Slightly cultivated podzolic gley fine clay loam	5,6	4,7	10,7	98,8	5,1	5,1	98	98
Cultivated podzolic gley fine clay loam	9,5	8,7	14,7	14,1	5,2	5,3	100	103
			Average		5,1± ±0,1	5,2± ±0,2	99± ±1	100± ±5
Magnesium content								
Slightly podzolic, slightly cultivated sandy loam	0,6	1,5	3,2	4,0	2,6	2,5	97	95
Slightly podzolic, well cultivated fine clay loam	3,9	5,1	6,4	7,7	2,5	2,6	93	97
Slightly cultivated podzolic gley fine clay loam	3,5	3,5	5,9	5,8	2,4	2,3	91	87
Cultivated podzolic gley fine clay loam	2,9	4,1	5,7	6,5	2,8	2,4	103	91
			Average		2,6± ±0,1	2,5± ±0,1	96± ±5	92± ±5

Note: Comma represents decimal point.

podzolic gley cultivated fine clay loam. The table shows the mean values of the additions found on analysis and also the standard errors for each result.

Our method of complexometric titration appears in all cases to give more accurate results than the classic methods. In this respect the data for magnesium are particularly indicative: although the final results of determining the added amount of magnesium include errors in four individual determinations, the total error in no case exceeds 0.2 meq per 100 g of soil.

It is noteworthy that the classic methods of analysis, as a rule, give lower results for calcium and higher for magnesium than does complexometric titration. The reason is evidently that large volumes of washings, in which appreciably amounts of calcium oxalate may be dissolved, are needed in order to flush the calcium oxalate precipitate free of chloride ions; the calcium which passes into the water is then determined along with magnesium.

Complexometric determination of exchangeable calcium and magnesium, as here modified, has the advantage over classic methods of analysis in that it is not only simpler and less laborious, but also more accurate. The method we used can therefore be recommended both for accurate laboratory investigation and for large scale determinations of exchangeable calcium and magnesium in NaCl and NH_4Cl extracts.

Summary

1. A modification of complexometric determination of exchangeable calcium and magnesium in soils is suggested, which ensures precise determination of the equivalence-point on titration of the total Ca + Mg, complete determination of calcium, and the possibility of direct determination of calcium in NH_4Cl soil solutions.

2. Comparison with the results obtained by the classic methods (the volumetric oxalate-permanganate method for calcium, the gravimetric pyrophosphate method for magnesium) indicate that the complexometric method is more accurate both in $NaCl^-$ and in NH_4Cl^- extract solutions from soils.

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ROLE OF CROP STUBBLE AND ROOT RESIDUES IN GRAIN—SUGAR BEET ROTATION IN SUPPLEMENTING THE ORGANIC MATTER AND MINERAL NUTRIENT BALANCE OF THE SOIL

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A most important element in investigating and devising a system of fertilizing grain-sugar beet rotations is discussing the importance of crop stubble and root residues supplying the soil with organic and mineral substances. It is essential to establish the amount of organic and mineral matter remaining in the soil along with the residues of roots and tops after the harvest.

Certain works (2, 3, 4, 6, 10, 12, 13, 15, 16, 17, 21) give information on the amount of root residues in respect of particular crops and their distribution down the soil profile in different regions. Considerable attention has been paid to the influence of agricultural practices, particularly soil cultivation and fertilizing, on the development of the root system and on the yield (5, 8, 11, 14).

There are data on the amount of roots and stubble and on their content of basic nutrients, relating to particular plants and, in some works, to all rotation crops (1, 7, 18, 20).

In our investigations the amount of crop stubble and root residues was taken into account in the rotation of a permanent field experiment with the following crop rotation: black fallow, winter wheat, sugar beets, barley with perennial grasses, first-year perennial grasses, second-year perennial grasses, winter rye, sugar beets, peas, winter rye. The grass mixture sown in the rotation was clover + alfalfa + fescue.

The soil was a thick, low-humus, solodized medium clay loam chernozem with a humus content in the plow layer of 4.2% and a 50-60 cm humus horizon.

Soil monoliths for all the plants were taken during the harvesting from paired control plots to which no manure had been added, but where mineral fertilizers had been added to the rows under sugar beets and winter wheat. The stubble and root residues of a vetch-fescue mixture of corn at the milky-wax stage of ripeness, spring wheat, and oats in a plot alongside the experimental plot were taken into consideration.

Method of Collecting the Stubble Root Residues and Their Analysis

A weight count of the roots was made during harvesting by taking soil monoliths and washing the roots from the soil with a water stream. The stubble was considered on the experimental plots.

In the case of the grain crops, peas, and grasses, the roots were collected from row sowings, the soil monolith being 50 cm long and 15 cm wide. For sugar beets the samples were 44.5 cm x 18 cm and for corn 70 cm x 70 cm. The sample was selected in the case of the continuous-row crops in such a way that the row of crops was situated in the middle of it. The depth of the monolith was 50 cm for all crops, and the sample was taken layer by layer; the depth of the first sample was 0-25 cm, the second was 25-35 cm, and the third was 35-50 cm. The samples were taken with 15 cm-wall, 5 mm mesh opening sieves and then washed. In the washing the bottom sieve had a 0.5 mm mesh opening. Washing was done with a weak-jet water stream. The advantage of this method is that the roots remain almost intact. To get rid of any other admixtures the entire mass of root residues in the test sample was given a further rinsing into a basin filled with water. The live roots, half-decayed residues from previous years and weed roots could then be distinguished according to their specific gravity (19), these fractions were then dried to absolute dryness and weighed. Triplicate samples of the roots made it possible to compute the amount of roots per hectare in the soil layer from which the soil monolith had been taken.

The plants were cut at the height taken in agricultural practice: winter wheat and corn at 15 cm, barley, peas, and the vetch-fescue mixture at 10 cm and perennial grasses at 5 cm.

The content of nitrogen and other elements in the roots was determined by taking parallel monoliths from which the roots were carefully picked by hand, then dipping them two or three times in water so as to rinse off the soil particles and then drying them. This method of preparing the roots of the mature plants for analysis obviated the possibility of washing out nutrients. The dried samples were ground in a handmill. Total nitrogen content was determined by the Kjeldahl method, phosphorus by the Denige method (Levitskiy's modification), potassium by the volumetric cobalti nitrite method and calcium by the volumetric method (precipitation by ammonium oxalate).

Amount of Plant Stubble and Root Residues in a Rotation and Their Nutrient Contents

It can be seen from Table 1 that if we take the total yield of grain + straw as 100, the amount of roots in the winter wheat and barley is 15%-22%. In the perennial grass and vetch-fescue mixture the amount of roots is relatively high. The lowest relative root weight was for peas – 10. 5%. The perennial grasses greatly exceeded all the other crops as regards amount of root residues.

Winter wheat and the vetch-fescue mixture left similar amounts of root residues and half as much as the perennial grasses. Of the rotation crops, sugar beets left the smallest amount of roots. Some investigators have established that the root residue amount depends on the thickness of the root system in the crop concerned, the height of the yield, and the agricultural practices used. Although the yields shown in Table 1 for individual crops reveal no appreciable variations from one year to another, the amount of root residue does nevertheless increase, within the limits of the variations that do occur, in proportion to the yield in the case of winter wheat, barley, and sugar beets.

In comparison with the total amount of stubble-root residues, the amount also varies considerably from one crop to another. It is least in the case of winter wheat (45-56%) and highest in perennial grasses, vetch-fescue mixture, and peas. In barley the roots constitute a large proportion than in winter wheat. This weight ratio of roots and stubble is due to the cutting height. If the field surface is uneven or cloddy and if the wheat is beaten down the stubble amount is usually higher.

The amount of roots was calculated at a depth of up to 50 cm, as the proportion of roots in the deeper soil layers is negligible. The results of these investigations are shown in Table 2.

Taking the average for all crops, except sugar beets corn, we have the following root proportions: in the 0-25 cm layer, 89. 0%; in

Table 1

Amount of stubble and root residues, centners per ha (absolute dry mass) 1958-1959

Crop	Year	Yield				Percentage of roots from		Stubble-root residue from previous crops
		Grain, roots, gr. mass	Hay, chaff, haulim	Roots in 0-35 cm layer	Stubble[a]	All stubble-root residue	Gross yield	
Winter wheat	1958	25,4	53,3	14,91	12,10	55,2	18,9	3,68
Same	1959	34,8	77,3	17,20	15,91	52,0	15,4	3,11
Average	—	30,1	65,3	16,0	14,00	53,6	17,2	3,40
Sugar beets	1958	181,0	102,0	4,16	—	—	—	—
Same	1958	253,0	115,0	5,26	2,50	—	—	4,39
Average	—	217,0	109,0	4,71	—	—	—	—
Barley	1958	23,5	29,8	8,01	6,13	56,7	15,2	—
Same	1959	22,5	32,4	7,52	5,60	57,3	13,7	2,27
Average	—	23,0	31,1	7,76	5,87	57,0	14,5	—
Second-year utilization perennial grasses	1958	—	36,5	35,58	8,10	81,5	97,5	4,80
Winter rye	»	24,8	33,3	12,57	11,35	52,5	21,6	14,71
Same	1959	27,1	53,8	13,45	15,87	45,9	16,6	15,19
Average	—	26,0	43,6	13,00	13,61	49,2	19,1	14,95
Sugar beets	1959	216,0	156,0	4,61	2,60	—	—	9,72
Peas	1958	25,8	32,7	6,16	2,12	74,4	10,5	4,35
Winter rye	1959	22,6	52,0	15,28	12,03	56,0	20,5	1,54
Total for rotation	—	—	—	103,20	60,80	—	—	45,40
Vetch-fescue mixture on hay	1959	—	54,2	16,10	8,64	65,0	29,7	—
Corn in milky-wax maturity for silage	»	423,0	—	11,34	7,33	—	—	—

[a] Top residues of sugar beets consisted of leaves, some of which remained in the field after the beets and tops had been harvested.

Note: Comma represents decimal point.

Table 2

Distribution of roots in root layer of soil, centners per ha (absolute dry mass) 1958-1959

Crop	Year	Weight of roots			Percentage roots		
		In soil layer, cm					
		0—25	25—35	35—50	0—25	25—35	35—50
Winter wheat	1958	14,18	0,73	0,73	90,6	4,7	4,7
Same	1959	16,28	0,92	0,95	89,7	5,1	5,2
Average	—	15,23	0,83	0,84	90,2	4,9	5,9
Sugar beets	1958	2,88	1,28	1,15	54,2	24,1	21,7
Same	1959	3,69	1,75	1,57	52,6	25,4	22,4
Average	—	3,29	1,51	1,36	53,3	24,7	22,0
Barley	1958	7,74	0,27	0,34	92,7	3,2	4,1
Same	1959	6,63	0.89	0.41	83,6	11,2	5,2
Average	—	7,18	0,58	0,37	88,1	7,2	4,7
Second-year utilization perennial grasses	1958	34,17	1,41	1,43	92,3	3,8	3,9
Winter rye		11.53	1,04	1,34	82,8	7,5	9,6
Same	1959	12,04	1,41	1,20	82,1	9,7	8,2
Average	—	11,79	1,25	1,27	82,5	8,6	8,9
Sugar beets	1959	3,39	1,22	1,07	59,7	21,5	18,8
Peas	1958	5,06	0,50	0,22	89,8	7,8	3,4
Winter rye	1959	14,57	0,71	0,68	91,3	4,4	4,3
Total for rotation		15,00	1,10	1,00	87,7	6,4	5,9
Vetch-fescue mixture on hay							
Corn in milky-wax maturity for silage	1959	9,58	1,76	1,19	76,4	14,1	9,5

Note: Comma represents decimal point.

the 25-35 cm layer, 6.0%; in the 35-50 cm layer, 5.0%.

The total amount of roots below the plow layer is 5.0% and only in the case of sugar beets is it larger (20.4%); so in order to compare the supply of organic matter to the soil from particular crops it is sufficient to determine the amount of roots in the plow layer. Root residues below this layer, however, must necessarily be taken into account, since they alone enrich the subsoil in organic matter.

Undecomposed stubble-root residues from previous crops and the roots of weeds were separated from the total roots by further washing. This was done for all the crops, as no manure had been applied to the plots in this

Table 3

Nutrient contents in roots and stubble, percent absolute dry matter[a]

Crop	N		P_2O_5		K_2O		Ca	
	Roots	Stubble	Roots	Stubble	Roots	Stubble	Roots	Stubble
Winter wheat	0,98	0,36	0,23	0,14	0,41	0,47	0,64	0,30
Winter rye	0,96	0,46	0,21	0,15	0,39	0,68	0,58	0,42
Spring wheat	1,10	0,55	0,18	0,14	0,22	—	0,66	0,49
Barley	0,68	0,42	0,21	0,20	0,25	0,84	0,64	0,44
Oats	0,86	0,40	0,28	0,25	0,32	0,34	0,75	0,42
Peas	1,60	0,69	0,35	0,28	0,27	0,52	1,10	2,81
Vetch-fescue hay	1,57	0,67	0,36	0,38	0,34	0,48	0,63	0,69
Sugar beets	1,35	2,20	0,36	0,40	0,54	2,97	1,33	1,97
Clover + alfalfa + fescue	2,37	2,00	0,54	0,54	0,49	1,14	1,11	1,28
Corn for silage in milky-wax maturity	1,33	1,21	0,31	0,35	1,00	—	0,66	1,30

[a] Analyst Z. A. Tur

Note: Comma represents decimal point.

experiment.

In 1959 the weed roots were calculated also for individual fields, with the following results (centners per ha): winter wheat — 0. 19, peas — 0. 61, barley — 0. 18, and winter rye after peas — 0. 35. In this case the weed roots taken into account was small and therefore had no significance in the root residue balance for each crop.

The amount of dry undecomposed stubble-root residues of previous crops (Table 1) after rotation made up 45. 4 centners per ha and the greatest amounts were found under winter rye sown after perennial grasses and sugar beets after the grass sod had been turned. After plowing the grass sod under the second crops in the rotation the amounts were four times greater than in the case of the first crops in the rotation, but under the last crops in both sections of the rotation the amount of undecomposed residues was similar. Second crops in rotation accordingly make greater use of nutrients released during the decomposition of stubble-root residues than do first crops.

Apart from the total amount of organic material left behind in the soil by plants, it is important to establish also the amount of nutrients contained in the stubble-root residues. As can be seen from the values in Table 3, the potassium percentage in the stubble of all plants is higher than in their roots. As regards nitrogen content, the roots of all the plants for which we have given values are richer than the stalks.

No such pattern is observed in the relative content in phosphorus and calcium. In all grain crops and in peas the roots contain more phosphorus than the stubble. In the remaining plants the phosphorus content in the roots and stubble is the same as in the top residues or higher.

All the grain crops contain more calcium in the roots, but peas, perennial and annual grasses, and corn have a higher calcium content in the stubble. The highest calcium content in all the plants was found in the top residues of peas. The largest amount of all nutrients is contained in the sugar beets residues.

The content of nutrients was determined separately in the roots and in the stubble. The nitrogen proportion in the stubble is very important, for when straw (8) or straw-manure with a wide C:N ratio is applied, biological tie-up of nitrogen occurs.

The total content of nitrogen, phosphorus, and other substances in the stubble-root residues of rotation crops, calculated per ha, depends on the amount of roots and stubble left by the crop in question. It can be seen from the values in Table 4 that perennial grasses leave particularly large amounts of nutrients along with the stubble-root residues, and in particular, large amounts of nitrogen, whereas peas, barley and sugar beets leave very small amounts of nutrients. Winter wheat occupies an intermediate position. As an annual average in the course of rotation 21 kg/ha of nitrogen, 5. 1 kg/ha of phosphorus, 10. 3 kg/ha of potassium, and 13. 7 kg/ha of calcium reach the soil with the stubble residues.

It follows from the preceding values that the importance of stubble-root residues from rotation crops in providing the soil with organic matter depends on the yield and composition of the crops.

The amount of root residues from all crops in the rotation studied, in centners per ha, was 103. 2, against 60. 8 of stubble and 164. 0 of total dry weight, corresponding in dry matter to 60 metric tons per ha of manure. The average amount of stubble-root residues is 16. 4 centners per ha annually. This does not include undecomposed stubble-root residues from previous crops, making up 45. 4 centners per ha of dry weight for the rotation. This can be taken as the carry-over reserve of organic

Table 4

Nutrient contents in roots and stubble residues, rotation, kg/ha

Crop	N	P_2O_5	K_2O	Ca
Winter wheat	20,78	5,17	13,16	14,48
Sugar beets	11,91	2,37	10,11	11,81
Barley	7,75	2,84	7,65	7,55
Clover + alfalfa + fescue	107,02	25,34	30,37	54,02
Winter rye	18,74	4,70	14,32	13,26
Sugar beets	11,94	2,70	10,21	9.59
Peas	11,32	2,73	2,76	12.74
Winter rye	20,20	4,94	14,14	13,91
Total for rotation	209,66	50,79	102,72	137,36

Note: Comma represents decimal point.

matter in the soil.

In regard to basic plant nutrients, the amount in kg/ha in the stubble-root residues from all crops in the rotation is, as has been mentioned, 210 for nitrogen, 51 for phosphorus, and 103 for potassium. If we take it that 20 metric tons of manure contains 100 kg of nitrogen, 50 kg of phosphorus and 120 kg of potassium, the stubble-root residues from all plants in this rotation contain the same amount of nitrogen as 40 and the same amount of phosphorus and potassium as 20 metric tons of manure.

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EFFECT OF TEMPORARY EXCESSIVE WETTING ON THE GROWTH AND DEVELOPMENT OF CORN AND INCREASE OF SALT CONTENT IN SURFACE SOIL

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Moisture deficiency in soil retards plant growth processes and disturbs the normal course of metabolism in the plant organism (15). There is an immense literature on plant (crops and wild plants) resistance to moisture deficiency. The results of numerous investigations in this direction have been put into monograph form by Maksimov (14), Genkel' (2), Sergeyev (18) and others. The influence of excessive wetting of the soil on plant growth and development, however, has hardly been touched by experimental investigation and only isolated works on this topic can be cited (1, 19, 21, etc.).

On the collective and state farms working on irrigated, diked areas of the Volga bottom lands and delta excessive wetting of soil under agricultural crops is often observed, particularly in the initial growth stages. This is due to the rise and escape of ground waters at the soil surface at the end of the spring floods, and also to the fact that when large amounts of water are used in irrigation the irrigation waters make contact with ground-waters lying near the surface. In both cases the plants develop for some time under conditions of temporary excessive-moisture.

To study the influence of such wetting on the growth and development of plants and also on the dynamics of salt content in the soil we carried out a special experiment in 1956 on fields of the Kamyzyakskogo base station in the Astrakhanskaya State Agricultural Experimental Station. A more or less uniform plot which had been under a experimental sowing of winter wheat was selected for this purpose. The plot has an elongated shape with a slight incline towards the main irrigation channel and lies near the ground water level, which varied on the average from 125 cm to 75 cm at the extremities of the plot for sowing.

Corn of the hybrid variety Slava was chosen as the experimental plant. After late fall plowing, sowing was done by the square-nest method (70 x 70 cm) on May 12th. When the corn reached the 3-5 leaf stage a first irrigation was applied by flooding the furrows at the unusually high rate of about 1200 m³ of water per ha. This caused the irrigation waters to make contact with the ground waters over a considerable part of the plot, with resultant excessive wetting which on various maps continued from five to 45 days. The plot was then divided into three parts: 1) excessive-wetting for five to eight days; 2) excessive-wetting for 18 to 25 days; 3) excessive wetting for 40 to 45 days.

A plot situated alongside, 0.1 ha in area, which had not been subjected to temporary excessive wetting, was used as the control.

Two further irrigations were applied to the areas where excessive wetting lasted until 5-8 days before the end of growing season and the ground water level was lowered to 70 cm, and 100 cm: one before tasseling and one under the grain-forming stage. Only one additional irrigation was given in plot 2, at the end of the flowering period, while no irrigation was applied to plot 3 before growth finished, since here the ground-water level did not fall below 20-30 cm before the grain reached milky stage of maturity. The excessively wetted corn was irrigated at the low rate of roughly 350-450 m³ per ha, in such a way that the soil moisture was kept at 55%-65% of the critical field moisture capacity. The control plot was irrigated five times: in the 3-5 leaf stage, 15 days later, before tasseling, at the end of flowering and during the felling of the ear. As in the other plots the low moisture threshold was kept at roughly 55%-65% of critical field moisture capacity.

In each treatment the plots were examined at the milky-wax stage of the grain maturity and certain elements in the yield structure were determined (Table 1).

Table 1 shows that excessive-wetting as a result of rise and escape to the surface of ground waters and also resulting from irrigation with large amounts of water, has an adverse effect on the development of the plants, which in the first instance inhibits growth processes. The longer the plants are subjected to excessive wetting, the more obvious is the loss of height and of length and width of the leaf blade. With excessive wetting for 40-45 days, for example, the height of the plant was one-seventh, the length of the leaf blade was only just over half and the width of the leaf blade only two-thirds of the control size. With 18-25 day wetting the height was reduced by a factor of almost 2, the leaf length by a factor of 1.1 and its width by a

Table 1

Influence of temporary excessive wetting on the growth and development of corn

Duration of wetting, days	Plant height, cm	5th leaf		Number of ears per plant	Length of ear, cm	Weight of ear, g
		Length	Width			
		cm				
Control (without wetting)	206,2	71,2	7,4	2,8	16,1	359,6
Wetting 5— 8	202,1	74,2	7,9	2,0	14,8	301,3
" 18—25	119,0	61,0	5,1	1,2	11,4	193,5
" 40—45	30,0	41,6	2,8	0,2	8,5	45,2

Note: Comma represents decimal point.

Table 2

Corn root formation in the milky-wax stage (average of ten measurements)

Duration of wetting, days	Penetration root system, depth, cm	Diameter of root system, cm	No. of root nodes
Control (without wetting)	118,5	131,6	70,9
Wetting 5— 8	107,2	108,8	62,6
" 18—25	47,0	73,3	45,5
" 40—45	28,3	53,0	30,2

Note: Comma represents decimal point.

Table 3

Chemical composition of ground waters of diked parts of volga delta

Object of investigation	Cl	SO_4	Total hardness degrees	Depth to water, m
	mg/liter			
Excessive wetting of water	27	2325	94	—
Observation wells along profiles	4906	2664	78	2,3
Boreholes	9542	2353	119,38	1,84

Note: Comma represents decimal point.

factor of more than 1.4 as compared with the control. Keeping the plants under excessively wet conditions for a short time (5-8 days) had less effect in retarding the growth processes, by comparison with the other two treatments.

Retarding the growth processes through excessive wetting greatly affected the female flower clusters and ear formation (average – 2.8 ears per plant in the control plot, against 2 ears in plot with 5 to 8 days of wetting 1.2 ears in 18 to 25 day plot, and 0.2 ears in 40 to 45 day plot). The number of ears per plant, their length and their weight decreased the longer the plants were subjected to excessive wetting.

Temporary excessive wetting of the soil thus affects the growth processes and reduces the corn yields, just as much as soil moisture deficiency. A similar connection between excessive wetting and yields was established by Skazkin (19), who found that excessive wetting of the soil influenced the ear formation and yield of barley to roughly the same extent as moisture deficiency.

Excessive wetting of the soil adversely affects not only the growth of the tops of corn but also to a considerable extent the character of the development and the depth to which the root system penetrates the soil.

As Kruzhilin's investigations have shown (10), normal soil moisture with irrigation allows the root system of corn to penetrate the soil during the waxy stage to a depth of more than 120 cm and to spread laterally to 145-240 cm at a depth of 8-12 cm.

According to our investigations, a surface root system forms in corn plants developing under conditions of excessive wetting and its penetration into the soil follows the level of the ground waters, the roots never reaching the water table but invariably spreading at roughly 8-12 cm above it. Metsävainio (22), Petrov (16), Lupinovich (13), Krasovskaya (9), and Godnev and Terent'yev (3) have also indicated the relationship between the root system development and the ground-water level.

As Krasovskaya (9) notes, the surface development of the root systems under conditions of excessive wetting of the soil is due to the fact that most agricultural plants are not adapted to inadequate aeration in the soil, as they lack aeration tissue and are consequently highly sensitive to flooding, particularly at high summer temperatures. The influence of excessive wetting on the initial growth stages of the plants continues to affect the development of the root system until the end of growing season and the longer the plants develop under such conditions the stronger is this effect (Table 2). Temporary excessive wetting not only adversely affects the growth and development of the plants but also leads to intensive salinization of the root layer of the soil with salts injurious to plants.

According to Kovda (6, 7), the Volga delta soils have a tendency to salinization and accumulation of chlorides and sulfates in the surface layers. According to Usov (20) the sources of salinization are the recent salt deposits of the Caspian Sea, which are parent material, and the ground-waters bedded comparatively near the soil surface and containing large amounts of chlorides and sulfates of alkali metals.

Table 3 gives data, taken from Kuzin (11), on the salt content in ground waters of diked areas of the delta.

On the diked areas of Volga river salinization processes are particularly intensified when the ground-water level rises during flooding, to emerge at the soil surface, mainly in the low-lying parts, and also when irrigation waters contact the ground-waters during irrigation.

In such cases, as the top layers of the soil dry out, the capillary rise of water becomes more intense. Considerable amounts of salts concentrated in the top layers of the soil are released from the evaporated water. In the end, after a short period of usefulness, previously fertile land is lost to agriculture owing to secondary salinization processes.

We traced the change of salt content in the soil of the plots sown to corn, determining the salt content first before "wetting" (after sowing) and secondly before the corn was harvested, that is, 100-60 days after temporary excessive wetting. In the first case, soil samples were taken for salt analysis from six points along the diagonal of the plot and an average sample was taken. Before harvesting, samples were taken from areas subjected to excessive wetting for various numbers of days, from two points of each plot, and an average sample formed from these. The salt content in the soil after planting corn is shown in Table 4.

As the data in Table 1 show, before temporary excessive wetting set in the experimental plot was characterized by a relatively low salt content. The total water-soluble salts in the 0cm to 60 cm depth was 0. 362%, varying from 0. 134% to 0. 490% in the different horizons. The Cl^- and SO_4^{--} content was also low. The least salinized level was the plow layer (0-20 cm).

Before harvesting, radical changes, as a result of temporary excessive wetting, occurred in the salt content in the soil (Table 5).

The amount of water-soluble salts in the soil by the end of the growing period of corn rose considerably in the excessively wet plots as compared with the original content (Table 4); the longer the excessive wetting continued, the higher the salt content in the soil, particularly in the surface layers. In the 0-10 cm layer, 40-45 days wetting increased the total content of all salts almost sixfold, the Cl^- content more than ninefold and the sulfates by a factor of 1. 5. Eighteen to 25 days wetting increased the salt content in the same soil layer, in density of residue, more than threefold in the case of Cl^- and by a factor of 1. 5 in the case of $SO_4^{=}$. In plot with 5-8 days wetting the Cl^- content was found to change hardly at all and only the density of residue of $SO_4^{=}$ slightly increased.

The less intensive accumulation of salts in the surface soil horizon (0-10 cm) during brief excessive wetting is due to the fact that after the soil moisture was reduced and the ground-

Table 4

Content of water-soluble salts in soil after planting corn before first irrigation, %

Depth, cm	Compact residue	Cl^-	$SO_4^{=}$
0 —10	0,134	0,017	0,133
10—20	0,194	0,037	0,056
20—30	0,400	0,101	0,081
30—40	0,490	0,138	0,051
40—60	0,474	0,146	0,123
0 —60	0,362	0,098	0,094

Note: Comma represents decimal point.

Table 5

Content of water-soluble salts in soil in relation to duration of wetting, %

Depth, cm	Density of residue	Cl^-	$SO_4^=$	Depth, cm	Density of residue	Cl^-	$SO_4^=$	Depth, cm	Density of residue	Cl^-	$SO_4^=$
5—8 days				18 — 25 days				40—45 days			
0—10	0,284	0,017	0,146	0—10	0,426	0,057	0,210	0—10	0,770	0,163	0,214
10—30	0,460	0,014	0,289	10—20	0,711	0,067	0,338	10—20	0,882	0,181	0,361
30—40	0,434	0,018	0,262	20—30	0,502	0,071	0,293	20—30	0,860	0,206	0,306
40—60	0,266	0,018	0,175	30—40	0,686	0,073	0,352	30—40	0,948	0,149	0,306
0—60	0,362	0,016	0,223	40—60	0,432	2,050	0,275	40 —60	0,680	1,112	0,423
				0—60	0,432	0,061	0,291	0 —60	0,803	0,154	0,341

Note: Comma represents decimal point.

water level fell somewhat, the corn plants started to develop intensively and shaled the soil surface. As a result moisture evaporation gradually ceased from the surface soil layers, so that salt accumulation in them diminished also.

Subsequent irrigation during the growing season with small amounts of water further desalinized the surface soil.

With prolonged excessive wetting, the conditions governing salt accumulation in the surface layers build up differently. The corn plants which have been in a depressed condition for a long time can no longer accumulate a sufficient vegetative mass to enable them to shade the soil after the surface has dried out and the ground water level has fallen to a certain limit. As a result, under the influence of capillary rise of water in the surface layers, there is intensive salt accumulation, and the incompletely recovered plants suffer "secondary" depression.

In the diked areas of collective and state farms in the Volga bottom lands and delta irrigation entails considerable annual losses from failure of vegetables, melons and grain crops. This results from excessive-wetting of the soil during the flood period, when excess moisture causes greatest damage to agricultural crops in low-lying areas and in areas where ground-waters lie near the surface.

Apart from indirect damage to cultivated plants, such as we have seen previously, secondary soil salinization processes intensify under the influence of excessive wetting, very soon reducing part of the irrigation lands to a state suitable for agricultural use.

The following steps can be recommended in order to preserve the irrigated lands and make the best use of them and at the same time eliminate the adverse effects of temporary excessive wetting on the growth and development of the plants:

1) regulation of irrigations by keeping to certain times, rates, and practices;

2) sowing plots, which periodically suffer repeated excessive wetting, to perennial forage grasses highly resistant to wetting and flooding; and

3) using land areas which suffer annual and prlonged wetting for tree plantation.

In all the irrigable Volga bottom land and delta lands where ground-waters lie near the surface irrigation during growing season must be at the low rate of roughly 300-400 m³ of water per ha, so as to prevent contact between the irrigation and the ground-waters. In view of the biological peculiarities of irrigated corn, the soil moisture and the ground-water level, irrigation with small amounts of water must be done rather more frequently. Normal irrigation system should not be adopted until the ground-waters have fallen to a certain level. The most acceptable method in this case will be to irrigate long furrows. Sprinkling should also be widely used and must be the main method of irrigating agricultural crops when ground-waters lie near the surface, particularly during the first part of growing season.

Perennial grasses in areas suffering from periodic excessive wetting, owing to their strong root system and high shading and transpiration capacity, enable the ground-water level to fall quickly, paralyze the capillary rise of water and thereby prevent salt accumulation in the surface horizons. In addition, sowings of perennial grasses make it possible to increase the production of forage, a very important point for many collective and state farms in the Volga bottom lands and delta.

According to Pshenichnyy (17) the following species of perennial grasses tolerate wetting and flooding: timothy grass (Phleum pratense L.) 43-54 days, meadow fescue (Festuca pratensis Huds.) 17-18 days, red fescue (Festuca rubra L.) up to 35 days, meadow foxdale (Aleopecurus pratensis L.) 32-54 days, fiorin (Argostisalla L.) 32-56 days, rough-stalked meadow grass (Poatriviacis L.) 18-35 days, awnless brome grass (Bromus inermis L.) 56 days, reed canary grass (Phalaris arundinaceale L.), quack grass (Agropyron repens P. B.) 30-42 days, white clover (Trifolium repens L.) 30-43 days, and pink clover (Trifolium nicridum L.) 45 days.

Our observations on Volga bottom land meadows, as well as direct investigations at the Kamyzyaskom base station in the Astrakhanskaya Agricultural Experimental Station showed that the most resistant species to prolonged flooding were awnless brome, canary grass, various species of fescue, and clovers.

The creation of forest plantations in places suffering annual and prolonged excessive wetting enables the ground water level to be lowered considerably. Numerous investigators (4, 5, 8, 12 and others) have established that many forest tree species possess considerable resistance to wetting and flooding. These include various species of willow, poplar, elaeagnus, Pennsylvanian ash, and others. Under Volga soil and delta conditions the English oak is also highly resistant.

Apart from drainage and other melioration measures involving considerable capital expenditure, the precautions mentioned previously make it possible to use irrigable land to the best advantage, prevent secondary soil salinization processes and increase the yield of cultivated agricultural crops.

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METHOD USED IN THE USA IN INVESTIGATING CLAY MINERALS

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On closer acquaintance with the literature on methods and after visiting certain specialized soil laboratories during the Seventh International Congress of Soil Science and taking part in the excursions arranged during the Congress, we now have a general impression of the systems of methods built up in the United States for studying high-dispersion soil minerals. We owe this largely to the great consideration with which we were treated by Professor M. L. Jackson, the distinguished authority on soil mineralogy and chemistry who occupies the Chair of Soil Science at the University of Wisconsin, Madison. A number of university faculties, including the Faculty of Soil Science at Wisconsin, are training highly qualified specialists drawn from young scientists sent there from other sections of the United States and many other countries. To this end, manuals on theoretical and experimental aspects of soil, physical chemistry, and mineralogy have been compiled.

Two schemes of investigating soil minerals, compiled by Professor Jackson, were published as part of the Congress documentation and distributed to delegates.

The first scheme (see Fig. 1) shows how the soil mass is divided into a number of separates for mineralogical analysis.

1. After removal of the gravel fractions, the soil is treated with a normal solution of sodium acetate, buffered with acetic acid to pH 5, boiled for 30 min and washed with the same solution to remove gypsum, calcium, and magnesium carbonates and water-soluble salts. The salts are determined in the filtrate.

2. The solid phase (residue) is centrifugally separated and the organic matter in it oxidized with a 30% H_2O_2 solution while being heated to 25°C and then to 100°C. The substances passing into solution are removed by repeated treatment with the above-mentioned acetate buffer solution (pH 5). Cations, along with the SiO_2 and Al, are determined in the filtrate.

3. The solid phases (minerals, including hydrates of iron oxides) are separated by centrifuging. The removal of the iron oxides, including their crystalline forms, is done by treating with a dithionate buffer consisting of $Na_2S_2O_4$ + $NaHCO_3$ + Na-citrate (pH 7.3, E_{OX} 0.65); the suspension is flocculated by treating with NaCl. Fe_2O_3, along with SiO_2 and Al_2O_3, are determined in the filtrate.[1]

4. The residue consisting of minerals cleaned to humus, salts, carbonates, and amorphous hydroxides, is boiled for 5 min in a 2% solution of Na_2CO_3; silica and aluminum are determined in the decantate.

5. Material is suspended in water and the suspension left in a cylinder. The material obtained after particles have fallen from a height of 5 cm for 40 sec is decanted and passed through a 300 mesh sieve. Particles of diameter greater than 50 μ (sand) remain in the sieve.

5a. By dry-sieving the material from the cylinder through a 140 mesh sieve, the coarse sand (2 mm — 100 μ in diameter) and fine sand (100-50 μ in diameter) are separated.

6. The silt and clay fractions < 50 μ in diameter contained in a suspension which has been passed through a 300 mesh sieve (see previous paragraph 5) are separated by leaving to stand and pouring off a liquid layer 5 cm high 2 min after agitation. Coarse silt (50-20 μ in diameter) collects in the sediment, silt, and clay < 20 μ in diameter) in the decantate.

7. The decantate is centrifuged for 3 min at 750 rpm. Medium and fine silt (20-2 μ in diameter) are in the sediment and the fraction < 2 μ in diameter (clay) into the decantate.

8. To separate the sediment into two subfractions (20-6 μ and 6-2 μ in diameter) it is again dispersed and transferred to suspension which is repeatedly centrifuged for 3 min at 300 rpm. The 20-6 μ diameter (medium silt) fraction collects in the sediment and the 6-2 μ diameter

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[1] See the remarks on methods of dissolving iron oxides in the paper by E. Mehra and M. L. Jackson, Iron oxide removal from soils and clays by a dithionate -citrate system buffered with sodium bicarbonate, Seventh National Conference in Clays and Soil Minerals, Washington, 1956. Reprinted 1960.

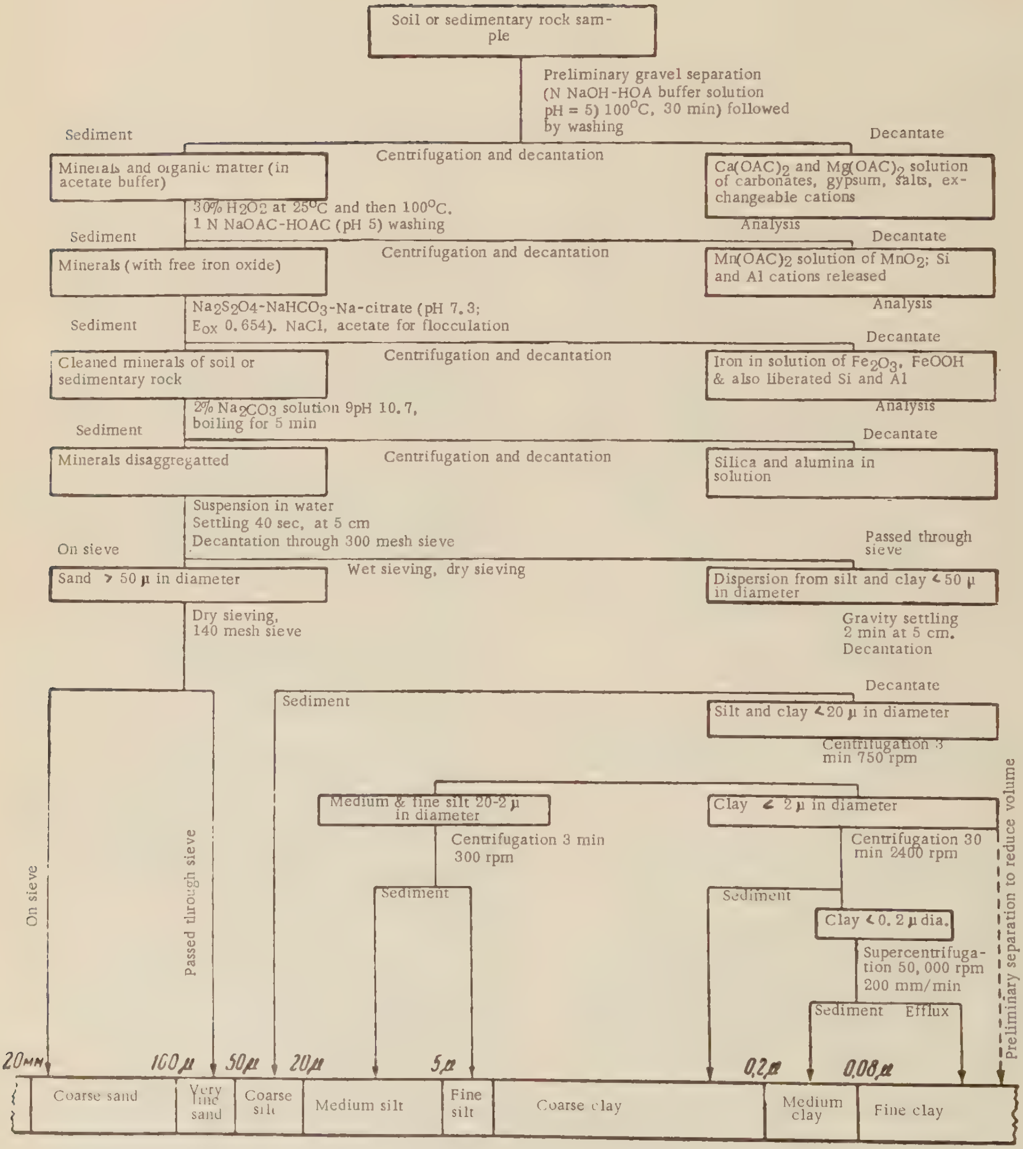
Soil or sedimentary rock sample
Preliminary gravel separation (N NaOH-HOA buffer solution pH = 5) 100°C, 30 min) followed by washing
Sediment
Decantate
Centrifugation and decantation
Minerals and organic matter (in acetate buffer)
Ca(OAC)2 and Mg(OAC)2 solution of carbonates, gypsum, salts, exchangeable cations
30% H2O2 at 25°C and then 100°C. 1 N NaOAC-HOAC (pH 5) washing
Analysis
Sediment
Decantate
Centrifugation and decantation
Minerals (with free iron oxide)
Mn(OAC)2 solution of MnO2; Si and Al cations released
Na2S2O4-NaHCO3-Na-citrate (pH 7.3; Eox 0.654). NaCl, acetate for flocculation
Analysis
Sediment
Decantate
Centrifugation and decantation
Cleaned minerals of soil or sedimentary rock
Iron in solution of Fe2O3, FeOOH & also liberated Si and Al
2% Na2CO3 solution 9pH 10.7, boiling for 5 min
Analysis
Sediment
Decantate
Centrifugation and decantation
Minerals disaggregatted
Silica and alumina in solution
Suspension in water
Settling 40 sec, at 5 cm
Decantation through 300 mesh sieve
On sieve
Passed through sieve
Wet sieving, dry sieving
Sand > 50 µ in diameter
Dispersion from silt and clay < 50 µ in diameter
Dry sieving, 140 mesh sieve
Gravity settling 2 min at 5 cm. Decantation
Decantate
Sediment
Silt and clay < 20 µ in diameter
Centrifugation 3 min 750 rpm
Medium & fine silt 20-2 µ in diameter
Clay < 2 µ in diameter
Centrifugation 3 min 300 rpm
Centrifugation 30 min 2400 rpm
On sieve
Passed through sieve
Sediment
Sediment
Clay < 0.2 µ dia.
Supercentrifugation 50,000 rpm 200 mm/min
Sediment
Efflux
Preliminary separation to reduce volume
20мм
100µ
50µ
20µ
5µ
0.2µ
0.08µ
Coarse sand
Very fine sand
Coarse silt
Medium silt
Fine silt
Coarse clay
Medium clay
Fine clay

Fig. 1. - Flow-sheet for quantitative mineral analysis of clay fraction.

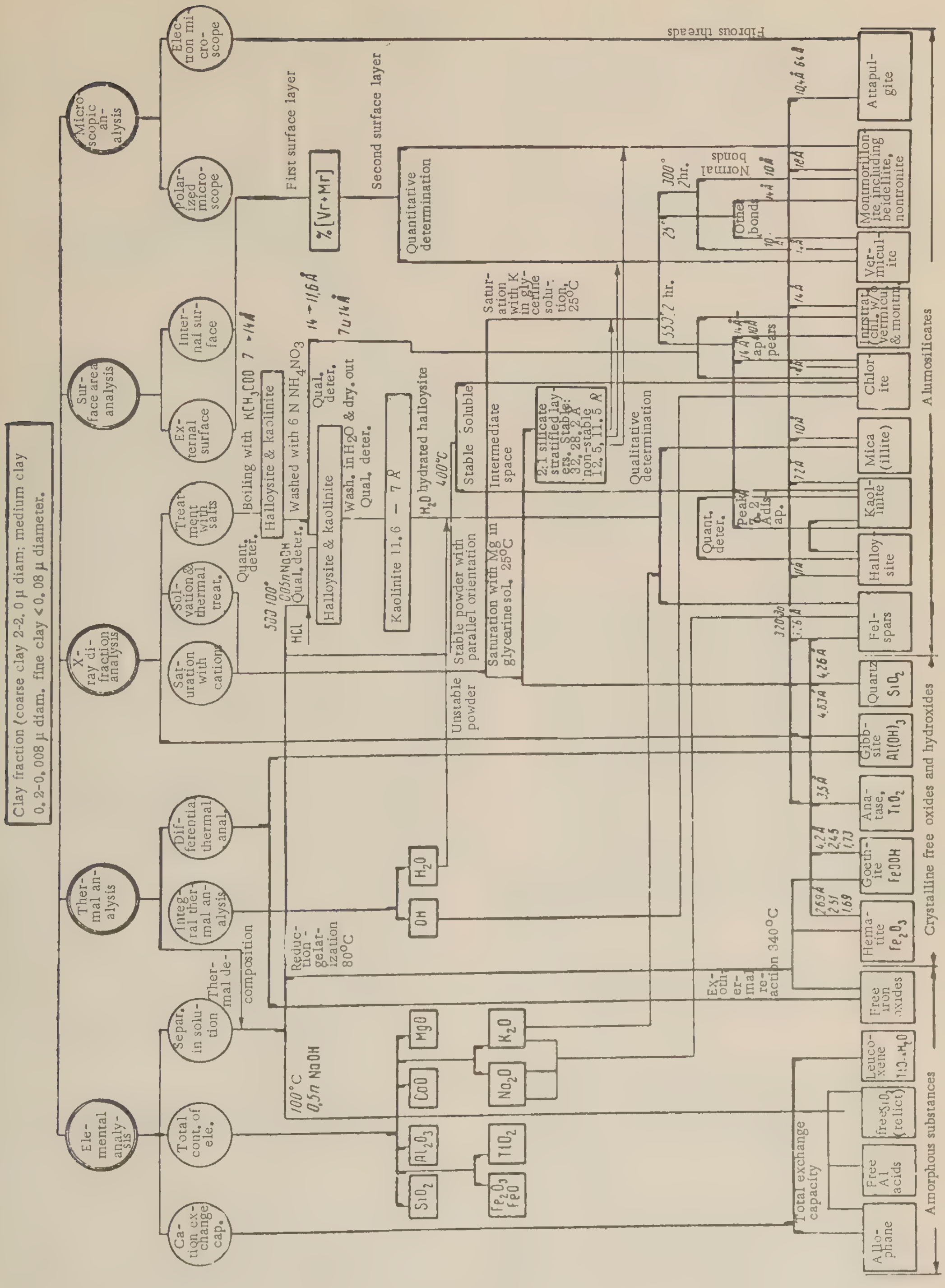

Fig. 2. - Flow-sheet for separation of colloidal fraction soil minerals and their isolation for analysis (after M.L. Jackson, Seventh Congress of the International Society of Soil Science, August 15-23, 1960.

(fine silt) in the decantate.

9. A clay suspension (< 2 μ in diameter, see 7 above) is centrifuged for 30 min (2400 revolutions). The fine silt and medium clay (6. 0-2 μ in diameter) are sedimented and the less than 0. 2 μ diameter fraction remains in suspension.

10. Supercentrifuging (Sharpleys) at 50, 000 revolutions at a flow rate of 200 ml per min. Medium clay (0. 2-0. 08 μ in diameter) is collected on sleeve, fine colloidal, or ordinary clay (< 0. 08 μ) is decanted.

Each fraction is determined quantitatively.

The second scheme (Fig. 2) is a flow sheet for quantitative and qualitative analysis of the mineral composition of the soil fractions separated. As can be seen, the coarse (2-0. 2 μ in diameter), medium (0. 2-0. 8 μ in diameter) and fine (clay < 0. 08 μ in diameter) fractions are subjected to the analysis system (total, chemical, thermal, X-ray, sorption for determining the specific surface area of the clay fraction, microscopic — (optical and electron microscope) —; the larger soil fractions are studied by optical and X-ray methods.

Chemical analyses. 1) Determination of the cation exchange capacity of the separated soil fractions by methods described in Jackson's book Soil Chemistry Analysis (First Course), 1958; 2) total analysis of the fractions indicated, the SiO_2, Al_2O_3, Fe_2O_3 and TiO_2 being determined colorimetrically and the CaO and MgO, Na_2O and K_2O by flame photometry; 3) differential extracts and their analysis; this includes determination of the free (amphoric) SiO_2 and Al_2O_3 in 0. 5 N NaOH extract at 100°C and, chemical separation of the free iron oxide appearing both in amphoric and in crystalline forms (hematite, goethite) by treating with a dithionate-citrate solution buffered with $NaHCO_3$ solution at 80°C (see above). If there is more than 5% of these forms of iron the amount of them contained in the sample is determined by thermal and X-ray methods.

Thermal analysis. This is both integral and differential. In the former case the dehydration curve is obtained by various methods.

The most complicated is the diffraction X-ray method for determining the mineral composition of the separated fractions. First non-orientated, then orientated samples are investigated. For further identification of the clay minerals the exchangeable cation effect on the diffraction picture which appears when clay minerals are saturated with magnesium or potassium is used.

A thermal effect is then used (modification of the basal OOL reflections of layered silicate clay minerals on heating): If minerals of the montmorillonite-nontronite group are saturated with glycerine the intra-packet space is as wide as 18 Å; after such samples have been heated to 500°C this narrows to 10 Å; in vermiculite minerals the corresponding values are 14 Å and 10 Å. If the value 14 Å remains unchanged after heating to 500°C this indicates a predominance of chlorite, but if the intra-packet space is 7 Å we have either chlorite or antigorite. The distance between the layers in the kaolinite lattice (7 Å) does not change on heating. Under the electron microscope it can be seen that many minerals can be distinguished by their form: attapulgite and halloysite, for example, have needle crystals. Determination of the specific surface of high dispersion minerals by using the values for monomolecular and dimolecular adsorption of organic fluids (methylglycol, glycol) has an important place in the investigation.

Jackson's book contains a fairly detailed exposition of the theoretical propositions and the techniques of performing the corresponding analyses.

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REVIEWS

A LOOK AT CANADIAN SOILS, AGRICULTURAL INSTITUTE REVIEW, OTTOWA, CANADA,1960[1]

I. S. ZONN

This book, containing 60 pages of printed text, 13 photographs, and 8 schematic maps, is a brief summary giving a fairly clear picture of the present state of Canadian soil science, its main trends, and the organization and methods of soil research.

The content of all the papers shows that interest centers mainly on soil classification, description of the main soil groups, and methods and organization of soil research. These are preceded by articles on the physical-geographical zones of Canada and the climatic and geobotanical characteristics of the different zones.

L. Chapman distinguishes the following physical-geographical regions: the Canadian shield, the interior plains, the Cordillera mountain region, the depressions of the Great Lakes and the St. Lawrence River, the Appalachians, the depression adjoining the Hudson Bay and the Arctic Archipelago.

The Canadian climate is of the temperate-cold continental type. The geobotanical map distinguishes a rocky arctic desert, a rocky sedge-moss-lichen tundra; a moss-lichen tundra with dwarf shrub; a forest tundra; arctic forests; the eastern hardwood forests; park aspen stand; medium grasslands and low grasslands. The Cordillera vegetation consists of alpine tundra, sub-alpine forest, intramontane forests, ponderosa pine coastal forests. The Niagara hardwood forests stands in a separate classification.

The main paper is by P. Stobbe, Director of the Soil Institute of the Canadian Department of Agriculture. This sets out the classification, genesis, and distribution of the main soil groups.

On the whole the Canadian soils are shallow and less weathered than those of many other countries, owing to their relative youth.

The great variety of soils studied and described in the literature can be reduced to a comparatively small number of "great soil groups". Each such group contains a number of transitional soils.

CLASSIFICATION OF CANADIAN SOILS

Podzolic soils	gray forest
	gray-brown podzolic
	podzols
	humic podzols[2]
Brown earths	brown coniferous forest
	brown broadleaved forest
Gley soils	brown podzolized
	brown concretionary[3]
Chernozems	brown[4]
	dark brown
	black
Solonetzic soils	solonetz
	solodized solonetz
	solod
Meadow soils	
Poorly developed (skeleton soils)	
Peaty soils	

On the basis of the foregoing classification, Canadian soil scientists distinguish a number of soil zones in Canada. These are clearly marked on the accompanying map. The soil zones are connected with the main physical-geographical, climatic, and geobotanical regions and with certain types of agriculture.

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[1] A look at Canadian soils, 60 pp. Agricultural Institute Review Ottawa, Canada, 1960.

[2] Humic podzols develop under more humid and cold conditions than gray forest soils, under heathlands, with the result that they have a relatively thick surface litter. The subjacent horizon has an intensive dark coloration and contains more than 10% of acid, unsaturated organic matter.

[3] Concretionary brown soils develop on acid rocks. They have a litter under which follows a brown or reddish-brown horizon of medium to high acidity and low adsorption capacity. Canadian soil scientists believe that these will eventually turn into podzols.

[4] The genesis of brown and dark brown soils, which belong to the chernozem group, is not clear. The term "brown soil" should evidently be taken to mean brown and light chestnut soils, as distinguished from the various subgroups of chestnut soils covered by the term "dark brown".

1. Three soil zones are distinguished in the west Canadian grass region. A brown soil zone occurs in the most arid part of the region. The predominating brown soils form a cover along with various solonetzic soils, solonchaks in depressions, and with certain meadow and local poorly-developed soils.

In the dark brown soil zone, which receives the greatest amount of precipitation, these soils develop along with solonetzic, poorly-developed, boggy soils with solonchaks in the depressions.

A black soil zone is situated in the more humid parts of the grass region, where chernozems proper form complexes with meadow and leached soils, and in places give way to slough podzols with alkaline, gray forest, and poorly-developed soils. Chernozem soils predominate in this zone but in some places occupy only a small part of the territory.

2. The gray forest soil zone is connected with the northern forests.[5] Gray forest soils developed primarily on calcareous rocks predominate in this zone, but gley soils occur in places. Meadow soils may form a substantial part of the soil cover along with alkaline and peaty soils. Brown forest and chernozem soils occur on calcareous rocks, podzols coincide with the non-calcareous rocks. In the gray-brown podzolized soils of Southern Ontario, gray-brown podzolized and dark-gray gley soils predominate. Brown forest and poorly-developed soils, as well as peaty soils, occupy part of the area.

The lowlands of the St. Lawrence river in the provinces of Quebec and Ontario are regarded as a soil zone because the parent rocks in this little-populated region are markedly different from those in the neighboring zones. Dark-gray gley soils predominate on the extensively developed fine-textured rocks, while podzols develop on the sands. Brown forest and, to a lesser extent, gray-brown podzolized and gray forest soils occur locally on limestones and brown podzolized soils on acid rocks. Peaty soils as well as gleys and poorly-developed soils occur sporadically.

3. In the southern part of the Canadian shield podzolic soils and podzols have developed in the well-drained areas. Peaty and gley soils are found in the poorly-drained depressions. Shallow, coarse poorly-developed soils have formed on the outcrops of parent rocks. Brown podzolized soils coincide with the southern edge of the shield. In this zone there are also many depressions made up of lacustrine carbonate deposits. Gray forest soils, along with gley soils and peats, form on lacustrine carbonate deposits.

4. The belt of subarctic tundra soils extends westward from the Canadian shield through the interior plants and on to the Cordillera. Most of the soils in this region have developed under conditions of permafrost, with the result that soil formation occurs only in the top layer, which periodically thaws. Here podzolic soils form where drainage conditions are better, while peaty, gley, and poorly-developed soils corresponding to the Soviet tundras coincide with the depressions. North of the tundra shallow peaty, gley, and poorly-developed arctic soils predominate.

5. An exceptionally wide variety of soils is to be expected in the Cordillera, owing to the great variety of soil-forming factors. In the dry regions we find various chernozems and brown soils. On many plateaus podzols and gray forest soils are found along with gleys. Brown forest, brown podzolic, and brown concretionary soils are often found, the latter in the south of the coastal region. The greater part of this region consists of mountain soils; there are many exposed rocks, glaciers, poorly-developed coarse-textured, and gley soils.

Soils of particular regions are described in more detail: Prairie Soils, by W. E. Bowser; Soils Under Forest in the Great Plain Region, by W. A. Ehrlich and W. Odynsky; the Cordillera Soils, by L. Farstad and C. A. Rowles; Soils of the Great Lakes and St. Lawrence River by R. Baril and B. Matthews; Soils of the Canadian Shield, by G. A. Hills; Soils of the Appalachians, by D. B. Cann and J. F. Millete; and Soils of the Arctic and Subarctic Region, by F. S. Nowosad and A. Leahey.

Because of the growing interest in problems of soil science in recent years the network of Canadian scientific research institutes is being enlarged and their scope extended. The organizational aspect of research is described by P. O. Ripley and H. J. Atkinson.

All research in soil science comes under the Federal Department of Agriculture, which is responsible for the Ottawa Soil Institute, seven research Stations, twenty-five experimental farms, and seven provincial substations. In addition, the universities perform a great deal of research as part of their teaching work. All work connected with tracing, mapping, and classifying the soils of Canada is done by the provincial Departments and by the soil science Departments of the provincial universities.

The Soil Institute has twenty-three research departments engaged in studying problems of national interest and theoretical aspects of soil science. The regional sections have about sixty soil scientists working on problems of local significance.

The Research Councils of the different Provinces deal with any particular problem that may arise. The following figures indicate the number of research projects on which Canadian soil scientists are working: genesis and classification — 19; fertility — 368; chemistry — 24; physics — 60; technology — 73; mineralogy — 10; microbiology — 19; total — 583 projects.

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[5] To judge from the morphological descriptions, the gray forest soils distinguished here correspond to those of the gray soils of forest steppe zone in the USSR.

Reconnaisance work is being done over an area of 200 million acres and about 1500 soil series have been discovered. Apart from soil mapping and description, considerable progress is being made in studying factors affecting soil development and classifying them on a taxonomic basis. At present laboratory study of these factors is essential in order to discover the genesis of various soil groups and establish the typical profile characteristics of the principal series.

All the scientific centers are carrying out field and laboratory work on the highly important problem of fertility. Efforts are directed mainly toward studying the proper use of the "three basic elements of fertility" — nitrogen, phosphorus, and potassium. Many aspects of this problem have already been studied, for example, the requirements of various crops in nutrients, the proper time and methods of adding fertilizers, and the optimum position of particular crops in rotation. Intensive research is being done on the agricultural use of micro-elements (cobalt, zinc, copper, molybdenum, sulfphur and others). Questions connected with the liming of acid soils are regarded as important. Scientists from the university of Saskatchewan pioneered the use of radioactive isotopes. The work has been done mainly with labeled phosphorus, but work with radioactive sulfur is now being done at the University of Alberta.

Soil chemistry research is aimed at reducing to more precise terms the conclusions drawn from soil mapping, fertility studies, and so forth. Efforts are being made to discover the chemical structure of humic and fulvic acids. Great attention is being paid to nitrogen. Attention is also being given to measuring the pH of soils and discovering factors influencing pH variation. The study of phosphates in soil is fundamental to an understanding of the fixation of phosphorus added as fertilizer. The interaction between magnesium and clay minerals is the subject of keen study. Canadian soil scientists are hoping to discover the importance of magnesium in solonetz formation and its role in neutralizing soil acidity in liming. The agronomical action of strontium 90 has lately aroused great interest in Canada.

In soil mineralogy it has been necessary to determine the mineralogical composition of Canadian soils and establish the typical mineralogical profiles for the large soil groups. Canadian soil scientists have undertaken to study the influence of soil formation on the mineralogical composition of soils. Great attention is being paid to the influence of low temperatures on the formation and structure of clay minerals, as a considerable part of the Canadian soils is formed under low-temperature conditions throughout the greater part of the year.

In the dry regions of South Saskatchewan, where moisture conservation and the struggle against wind erosion are of great importance, soil physics studies have been developed with the speed they deserve. Basic research on soil moisture, started many years ago, has continued and has produced much valuable information on the amount of soil moisture, its use in irrigation, its movement in the soil, capillary conductivity, and evapotranspiration. Studies in soil structure, texture, the dynamics of soil processes, and many other subjects have not been ignored. Interesting research is being done on the use of "thermogravimetry" in describing soils.

Great attention is being paid to technological problems. Under this heading come station observations over periods of many years on the influence of irrigation, drainage, erosion processes, the study of metereological factors such as temperature, precipitation, evaporation, the duration of solar illumination, the effects of frost on the soil, and so forth.

The foregoing is by no means a complete enumeration of the topics and problems covered by Canadian soil scientists. Since Canada lies in the same geographical latitudes as the USSR, we find many common features in the soils of the two countries and their distribution. The book here reviewed is therefore of interest to Soviet soil scientists.

CHRONICLE

SUMMARY OF A DISCUSSION ON THE BOOK "SOIL SURVEYS"

N. A. NOGINA, Scientific Secretary of the Fifth Committee of the AUSSS (VOP)

The All-Union Society of Soil Scientists (VOP) and its Fifth Committee arranged a discussion on the methods manual "Soil Surveys", compiled by staff members of the V. V. Dokuchayev Soil Institute, which appeared in 1959. The book had first been criticized at meetings of the Society's divisions and branches and the documents had then been sent to Moscow, where the Moscow soil scientists continued to discuss it jointly with colleagues from the Belorussian, Buryat, Azerbaydzhan, Smolensk, Kirgiz, Krasnoyarsk and Omsk branches and departments of the Society, representatives of the All-Union Institute of Fertilizers and Agricultural Soil Science, of the University of Moscow, of the Timiryazev Academy of Agriculture, and of Agrolesoproyekta, the Institute of Forestry, and the V. V. Dokuchayev Soil Institute. Fifteen of the Society's divisions sent in comments on the book (the Armenian, Bashkir, Voronezh, Georgian, Irkutsk, Kaluga, Latvian, Leningrad, Lithuanian, Mariyyskaya ASSR, Moldavian, Stalingrad, Tadzhik, Tomsk, and Estonian divisions). It is regretted that no response has been obtained from the Society's other branches and divisions, including the important Ukrainian and Belorussian divisions (Presidents A. M. Grinchenko and I. S. Lupinovich respectively), which have done much work on the detailed mapping of soils.

A large team was thus involved in the discussion, including soil scientists working in various natural regions and conducting soil surveys for a variety of purposes.

Most of the written comments and personal observations on the book praised it as the first work to discuss, at a high scientific level, not only the basic principles of field soil investigations but also specific aspects of such work for purposes of irrigation, draining, forestry and agricultural afforestation (Tomsk Div. AUSSS), and as the most comprehensive work yet to appear, which for the first time systematically assembles extensive data on the methods and techniques of soil surveying (Bashkir Branch AUSSS); the timeliness of the book and its great value to Soviet soil scientists is mentioned (Latvian Branch AUSSS), and O. V. Makeyev points out that it has found a wide readership among students, teachers in higher education, industrial soil scientists, and the staffs of experimental stations and regional institutes.

All the replies, on the other hand, contain also critical comments and suggestions for the second edition. It is impossible to give the gist of all these comments and suggestions in a brief report. They fall into three groups: 1) those relating to the manual as a whole (its contents and general plan): 2) those referring to particular sections of the book; 3) comments on particular propositions put forward in the manual. The first category of comments can be reduced to the following.

1. The specific requirements of soil surveying work in various natural zones at different scales do not clearly emerge. It is recommended that the general plan of the book be changed in the next edition and the material arranged so as to meet this requirement. At the same time, it was unanimously agreed that the manual should contain sections on soil surveys for different purposes.

2. A soil key, with brief diagnostic characters, must be included in the manual (possibly in a second volume) along with a clarification of the problems of classifying cultivated soils.

3. The different sections of the book are not sufficiently coordinated.

4. A section on methods of generalizing the information obtained from detailed soil surveys might be introduced, with rayon and Oblast' maps.

5. A new section on how to organize and run the systematic soil investigations planned as part of the organization of a soil conservation service would be desirable.

Comments and request in connection with the structure of individual chapters and sections of the book were more numerous and often contradictory. We shall mention only those which emerged most clearly and generally.

1. It was suggested that a section giving the nomenclature and characteristics of the genetic horizons of the different soil groups should be added.

2. The sections on the critique of analytical data should be greatly enlarged, by the inclusion of a wider selection of analyses, with detailed discussion of these and recommendations on the

of analytical material for practical purposes.

3. The manual contains no methodological indications on the grouping of soils into agriculturally productive groups.

4. A list of explanatory notes to soil maps and the content and number of schematic maps to be attached to them are not explained in sufficient detail.

5. It is recommended that the chapter on soil surveying in mountain territories be enlarged and a new chapter on the surveying of soils under orchards and vineyards be introduced.

6. A number of replies mentioned the first chapter of Part II ("soil research in relation to land management and farm planning in collective and state farms") was unsatisfactory and should be rewritten.

7. Disagreement with the method of determining the degree of stoniness (obstruction) of land was expressed.

8. The necessity for more detailed clarification of the problems entailed in mapping and classifying eroded soils was emphasized.

9. It was recommended that more attention be paid to the problems of using soil maps and the notes attached to them for practical purposes.

As the Leningrad Branch of the AUSSS had sent in an unfavorable criticism of the book, this criticism was read out at the Moscow Conference, but it was not approved, as it did not contain constructive suggestions. The Conference adopted the following resolution.

"The Fifth Committee of the All-Union Society of Soil Scientists, having discussed at an extended meeting the reports on the book 'Soil Surveying' received from divisions and branches of the AUSSS and having heard contributions from delegates present at the meeting, notes that on the whole this manual has been favorably received. In the course of detailed and serious criticism of the book, however, a number of comments and suggestions for improvement were expressed.

"Considering the expansion of soil cartographic work and in view of the creation of soil divisions attached to provincial soil stations, the Committee believes it desirable to start preparing a second edition of the manual 'Soil Surveying'. It is essential that in working on the second edition the editorial board and authors take into account all the records of the discussions that have taken place. Further, it would be desirable to enlarge the team of authors and create separate teams to consolidate the material in sections of the book. It would be desirable to include a list of soils with diagnostic characters and also to deal with the specialized aspects of soil surveying in different zones.

"The Committee considers that it would be appropriate to publish a brief review of the discussions on the book 'Soil Surveying' in the journal *Pochvovedeniye.*"

REPORTS ON SOIL SCIENCE PRESENTED AT THE 3RD ALL-UNION SCIENTIFIC CONFERENCE OF YOUNG BIOLOGISTS

R. M. ALEKSAKHIN and V. I. DUBA

It has become a tradition in the soil biology department of Moscow University to hold annual All-Union scientific conferences of young specialists in biology. The 1961 Conference was held in honor of the 250th anniversary of the birth of the great Russian scientist and thinker M. V. Lomonosov.

In his many-sided scientific career, Lomonosov contributed greatly to the development of all branches of science and was centuries ahead of his contemporaries. He did great service too in advancing soil science. As Academician V. I. Vernadskiy has put it, Lomonosov was not only the first Russian soil scientist, but the first soil scientist ever.

Lomonosov's views on soil and their importance in his day were discussed in a paper by V. A. Bol'shakov and V. I. Duda (University of Moscow) presented at the plenary session. The authors said that Lomonosov was the first to express the idea that soil is a product of the action of vegetation on parent materials under particular environmental conditions. This fundamentally important idea was not recognized until a hundred and fifty years later. Lomonosov described the soil formation process as follows: first the less demanding plants ("young moss") settle on rock surface ("rocky bare mountains"); when they did off their residues blacken and turn into soil ("earth"); in time ("with length of time") the amount of organic matter in the soil builds up and becomes suitable for larger more highly organized plants ("large mosses and other plants").

Lomonosov's works contained interesting remarks on the genesis and evolution of soils, the role of vegetation, rocks and climate in soil formation, zonality in the distribution of vegetation and soils, the incidence of solonchaks soils, and soil erosion. He developed one of the first theories of the land origin of chernozems.

Lomonosov's contribution to soil science was developed further in the work of the classical school of Russian soil science — Dokuchayev, Sibirtsev, Kostychev, and Vil'yams. Of particular topical interest to us is the great Russian naturalist's constant effort to relate the solution of scientific problems to concrete practical matters. When he compiled his "True and circumstantial Russian geography" in 1759, Lomonosov was interested in "what kinds of grain are most sown and whether it is useful to discuss the general profit before sowing." He wrote: "the true chemist must be a theoretician and a practical man."

The soil science commission heard and discussed fourteen papers by representatives from institutes of higher education in eight towns of the USSR.

Great interest and lively discussion was aroused by V. P. Yegorov's paper (Kazak State University) on problems of classifying the soils of the virgin territory in the Kazak SSR. The virgin territory had in recent years become one of the country's main granaries. The huge amount of work to be done there is regard to the large-scale mapping of soils for purposes of discovering new lands for reclamation and establishing sound principles for collective and state farm land management made it imperative to have a uniform classification of the territory's soils, on the basis of their genesis. An attempt was made in the paper to give a general classification of soils for all zones in the extensive virgin territory, based on eight years research material. The territory was divided on the zonal principle into a chernozem and a chestnut soil zone. The chernozems could be subdivided into rich, ordinary, and southern subgroups, and the chestnuts into dark chestnut, chestnut, and light chestnut soils. The subdivision into subgroups was connected with climatic variations within the limits of the soil-climatic zone. A further division into soil genera and species was determined by the influence of soil-forming rocks, relief, and other factors. Further subdivision into varieties reflected the diversity of soils as regards to texture. In the classification presented for discussion the existence of intrazonal soils was rejected, since in the author's opinion, because each of the soils that could be classified as intrazonal within the limits of a given soil-climatic zone the basic characters proper to the soil group of that zone were characteristic. Solonetzes in the chernozem zone, for example, differed from those in the chestnut zone only to the extent that chernozems differed from chestnut soils.

The papers dealt with the influence of cultivati on soil properties. N. G. Rudoy (Krasnoyarsk Institute of Agriculture) in a communication on "The change of certain elements in the fertility of chernozem soils in the Krasnoyarsk territory in relation to their cultivation" gave figures on the change of soil fertility in eleven state seed-testing plots over twenty years as a result of correct crop rotation, the addition or organic and mineral fertilizers and improved methods of tilling. It had been established that during the twenty years the humus content in the soil had increased, along with the available phosphorus compounds (1. 5-4 times) and nitrates, while the nitrification capacity of the soils had improved, the moisture storage in the subsoil had increased and water permeability had also improved. No clear improvement, however, had been recorded for certain indixes (content of exchangeable cations).

A. N. Tyurmenko (University of Kazan'), in a paper on "Changes in the physical and chemical properties of southern chernozems and dark chestnut soils in the Or'-Ilek watershed in the course of cultivation", reported on soil changes in North Kazakhstan as a result of plowing and prolonged tillage. The content of the soil in humus, total nitrogen and phosphorus, adsorbed cations, and available potassium compounds had been slightly higher in the virgin lands than in the old plowed soils. The decrease was due primarily to dilution of the top horizon of the virgin soils with soil, poorer in nutrients, from the lower horizon. The amount of available phosphorus compounds and hydrolyzable forms of nitrogen, on the other hand, was higher in the plow soils, owing to the transition of difficulty soluble compounds into a more available condition as the water-air regime of the virgin soils changed in the course of plowing and also as a result of the more intensive mineralization of the organic residues. The reduction in the amount of sodium taken up in the adsorbing complex of the plow soils was particularly noted. The amount of water-stable aggregates smaller than 0. 25 mm in diameter in the old plow soils was only just over half as much as in the virgin land. Newly-reclaimed soils occupied an intermediate position. Variation in the structural-aggregate composition was most marked in the plow layer and barely evident at all at a depth of 40-50 cm. The abrupt deterioration in the structural condition of the soils on plowing called for structural improvement action in the newly-reclaimed and old plow soils and above all for the introduction and general adoption of crop rotations with perennial grasses.

A paper by R. M. Aleksakhin (University of Moscow) dealt with the topical problem of investigating the behavior pattern of radioactive isotopes in the biosphere ("Some problems in the biological circulation of radioactive isotopes"). Undoubted progress could be noted in the study of biological circulation of a number of elements, which were for the most part absorbed by vegetation in macro amounts: C, N, P, S, K, Ca, Mg, Fe, Al, Si, and certain others, but data on the circulation of micro-elements and radioisotopes were almost non-existent. Knowledge of the migration of radioactive isotopes in the biosphere had increased in recent years owing to recognition of the special role of ionizing radiations, among the carriers of which were radioisotopes scattered in the biosphere; these were a powerful factor in the external environment and in the global contamination of the earth's surface with radioactive fragments. The specific distinguishing peculiarities of radioisotope circulation and the factors causing them were mentioned in the paper: 1) micro amounts of radioisotopes and the qualitative differences between their behavior in soils and that of macro amounts of isotopes of the same element; 2) phase conversions associated with radioactive decay (gas — solid, solid — gas, and so forth); 3) the influence of macro amounts of the chemically similar elements Ra-Ca, Sr^{90} — Ca, Cs^{137} — K, and the discrimination effect when pairs of elements move from the soil into the plants; 4) the presence among radioisotopes of genetically linked nucleids, belonging to chemically distinct elements and the fission effect associated with the interaction of radioisotopes and soil and the uptake of radioisotopes from the soil by plants. The author dealt in greatest detail with the chemical behavior of radioisotopes in soils, their methods of reaching the plants, the absorption patterns of the most important natural and artificial radioisotopes by plants (the heavy elements K^{40}, C^{14}, $Sr^{89,\,90}$, Cs^{137}, Zr^{95}, $I^{131,\,132}$, $I^{133,\,135}$, and others). Attention was drawn to the prospects of using labeled atoms in studying the biological circulation of nutrients.

A. D. Musayev (Azerbaydzhan Institute of Agriculture), in a paper on "Influence of micro-elements on cotton yield in Azerbaydzhan", indicated the prospects of introducing a number of micro-element fertilizers for cotton. The micro-elements improved absorption of nutrients, weakened the harmful effect of chloride in saline soils, accelerated plant growth, increased the oil and protein content in cotton seeds, and improved fiber yield. The following optimum amounts of micro-fertilizers had been established (in kg/ha): borax 2-4, manganese sulfate 5-10, copper sulfate 8, zinc sulfate 1, cobalt 1.

New data on the little-known subject of micro-element content in forest soils were given by Tran Kuan Ngay (University of Moscow) in a paper on "Micro-element content in soils under various forest plantations". Biological accumulation of a number of micro-elements in the top horizons of a podzol profile under green-moss spruce and a sod-highly podzolic soil profile under a motley grass birch stand in the Moscow province was demonstrated. Biological accumulation of Mn, Cr, and V exceeded that of Cu, Ni, and Co. The micro-element content increased in the soil fractions smaller than 0. 01 mm in diameter.

N. M. Syryy and S. M. Murza (Khar'khov Agricultural Institute), in a paper on "Influence of calcium-containing fertilizers on the yield of winter rye and the cultivation of podzolized chernozem in the Rovenskaya Oblast' Agricultural Experimental Station, " mentioned the effectiveness of using gypsums and defecation mud as calcium-containing fertilizers on the soils of West Ukrainian Oblast's, which were unsaturated with exchangeable bases, gleyed, structureless, and with a high exchangeable Al content. Liming did not always produce results in those soils. It had been shown in experiments in 1959 and

1960 that addition of three metric tons per ha of gypsum raised the winter rye yield by 3.4-3.8 centners/ha (14-18%) and addition of three metric tons per ha of defecate improved the yield by 7.4 centners per ha (33%). Combined addition of lime and gypsum (1.5 metric tons per ha) raised the yield by 7.2 centners per ha (34%). Addition of ground lime increased the yield by only 1.9-2.4 centners per ha (about 10%). Allowing for the fact that the yield increment in the soils in question resulting for the addition of twenty tons per ha of manure was 6.3 centners per ha (29%) against 7.9 centners per ha (36%) from addition of 45 kg/ha active principal of NPK, on an average yield of 28-29 centners per ha, it became clear that addition of three metric tons per ha of defecate or 1.5 metric tons per ha of gypsum and lime brought about the same result.

G. G. Vendilo (University of Moscow), in a paper on "Change in the quality of potato tubers as a function of soils and fertilizers," raised the question of how far soils influence not only the size but also the quality of the yield. Experiments had shown that addition of K and NPK helped increase the vitamin C content in potato tubers while addition of N and NK had hardly any effect in that respect. The highest starch concentration in potato tubers was found in varieties with NPK and without fertilizer. Addition of N and NK led to a decrease in the percentage of starch. The starch content in the tubers and its yield per ha were higher in medium cultivated than slightly cultivated soil. It was interesting that when potatoes were kept at temperatures above freezing-point (18-20°C) vitamin C decay was observed, amounting to 50%-55% by the end of the fourth month. Addition of N made for a higher content of total, protein and non-protein nitrogen in the tubers.

An original method of soil leaching model was suggested in a paper by Ibrahim Habib (University of Moscow) "Model tests of solonchak leaching". Leaching by the generally accepted method, using a glass cylinder fastened over a Büchner funnel, had been found to give a different percolate rate in the parts of the column near the walls and those at the center. To eliminate the influence of percolation near the walls a specially designed funnel had been used, which took the percolates separately; this enabled the percolation rate in the wall zone and in the axial part of the cylinder to be investigated. In a series of experiments it has been established that preliminary saturation of the soil column with water created great unevenness between the wall and axial percolations, while the use of a sand underlay in the water-collecting funnels distorted the results of the percolation. The suggested had been used to study the consequences of removing salts from solonchaks in the Bukhara depression of the Murgab oasis. The most mobile of the anions, as was to be expected, had been Cl^-. The first portion of water, equal to total moisture capacity, removed 97%-99% of the total output of sodium chloride from the soil. A large proportion of the sulfate salts (Na_2SO_4, $MgSO_4$) were removed with the same portion of water. In the author's opinion, leaching by the method used brought out a number of meliorative properties of soils.

S. Ye. Shcherbakov (Kirov Academy of Forest Technology) presented a paper on "Influence of mixed species of trees on the micro-complex constitution of forest soils". It had been established that in complex forest biogeocenosis in the Taygo belt trees of various species created their own specific complex in the soil (sod podzolic). Different tree species in the same plantation had a different effect on the soil; spruce affected the soil most strongly.

An interesting communication on methods, "Accuracy of analysis in colorimetric determination of micro-elements in soils and plants'" was read by Daniel Déry (University of Moscow). Taking as an example the determination of Mn, Zn, Cu, Co, and Mo content in samples from the plow horizon of a sod podzolic soil and a wheat grain, the author demonstrated the accuracy of the colorimetric method of determining micro-elements. A simple and rapid method of breaking-down soil by acid (the Rinkis method) gave a small error in the determination (a factor of 2 for Mn and of 3 for Cu). The mean standard error with this method was about 1%-2%.

A paper by R. M. Latypova (Belorussian Academy of Agriculture), on "Protease activity of sod podzolic soils and the influence of peat organic matter on it," dealt with the study of the soil activity of soil micro-flora exoenzymes (proteases). The conversion of organic nitrogen compounds in soil into forms readily assimilated by plants depended largely on the proteolytic activity of the enzymes. Comparison of the protease activity of lowland peat and soils showed that it was several times higher in the peat, and therefore the addition of this biologically active substrate enhanced the proteolytic activity of the soil. Enhancing the enzyme activity of the soil was invariably accompanied by improved yield. The activity of soil proteases under plants was a good deal higher than in fallow ground. The activity of proteolytic enzymes was determined largely by external environmental conditions. It improved from the beginning of the growing period until July and then slowly decreased. Further, protease activity was subject to considerable variation throughout the growing period, depending on the soil moisture: when moisture decreased to 4%-5%, protease activity decreased sharply but rose abruptly when the moisture content increased after rain.

Communications from D. D. Debelova (University of Moscow), on "Soils of the Il'yich Memorial Collective Farm, Khislavichskiy district, Smolenzk," and from S. G. Khruslo (University of Moscow), on "the influence of phosphate nutrition on the appearance of chlorosis in wheat," were heard.

A number of papers on soil science were discussed at meetings of the Microbiology, Agrobiology, and Agriculture sections.

The papers on soil microbiology dealt mainly with two questions: the distribution of micro-organisms in soils and the interrelationship between soil micro-organisms and plants. V. K.

Orleanskiy (University of Moscow), in a paper on "thermophilic actinomycetes in Pamir soils and their antagonistic properties," noted that the amount of thermophilic micro-organisms did not depend on height above sea level, but on the ecological environment and micro-conditions of the soil area. The number of such micro-organisms depended to an even greater extent on the soil group and degree of cultivation. In all the soils studied the widespread species Micromonospora vulgaris predominated. The number of antagonists among the thermophilic actinomycetes of the Pamir soils was 48% and in some cases as much as 95%.

The distribution, systematics, and physiology of soil yeasts are poorly covered in the literature and there was therefore great interest in papers by N. D. Savel'yeva (University of Moscow) on "The species composition and biological peculiarities of yeast flora from the rhizosphere of certain agricultural plants" and L. A. Golovl'yeva and I. T. Yermakova (University of Moscow) on soil yeasts Torulopsis pucherrima."

The first of these papers gave the results of systematic investigation of yeast flora in sod podzolic soil under different agricultural crops in the Moscow Oblast'. All the yeast strains distinguished belonged to 17 different species, some of which, such as Zygowilliopsis californicus and Williopsis saturnicus were, according to the literature, rare and their biology almost entirely unknown. A number of the physiological and biochemical peculiarities of the strains distinguished was studied.

In the second paper it was reported that asporogenic yeasts Torulopsis pucherrima were found in large amount in chernozems, bottom land soils, brown and gray forest soils. Some strains of the yeasts identified were capable of forming substances stimulating plant growth. However, verification of the liquid culture of active strains by the paper chromatography method in the presence of gibberellic acid did not yield positive results. The yeast strains tested possessed the capacity of synthesizing five groups of vitamin B, with the exception of biotin. Vitamin B_1 synthesized by yeasts was well retained by living cells and secreted into the surrounding medium only after their death.

Great interest attached to a paper by G. M. Zenova (University of Moscow) on "content of vitamin B group in soil during the growing period". She had established that during the growth period of carrots, the vitamin B content in sod podzolic soil increased, the inositol content per gram of air-dry soil rose from 17 μ g in June to 20 μg in September, and the nicotinic acid rose correspondingly from 3 μg to 4. 5 μ g and the vitamin B_6 content from 1 μg to 1. 7 μg. As compared with the control soil, without vegetation, where the vitamin content decreased towards the end of the growing period, the amount of bacteria and fungi in the experimental soil in the plant zone increased towards fall. As plants, in the course of their development, selected vitamins from the soil to supplement those they synthesized themselves, the results indicated that micro-organisms did add vitamins of group B to the soil.

The Conference made possible a wide exchange of views concerning the work on which the young specialists were engaged and strengthened contacts among young Soviet soil scientists. As compared with the two previous Conferences the number of papers on soil science had risen and more regions of the country were represented.

The next (fourth) All-Union Conference of Young Biologists is to be held in Kiev in 1963.

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